Sensor study

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Summary

- Compare different sensors
  - Sensitivity using ^{55}Fe source
  - Noise MEAN and STD
  - Telegraph noise

	Run Nr	Exposure time
ORCA Flash	2155	40 ms
ORCA Fusion	2358	30 ms
BSI Gain LG	2355	30 ms
BSI Gain HG	3520	100 ms

- Measure exposure time effect on FLASH sensor

File_ Number	saved_events	Exposure_Time_ms	comments
3 ottobre 2018 Orca Flash black - no lens			
817	100	10	camera only (blaked/no lens)
818	100	100	camera only (blaked/no lens)
819	100	1000	camera only (blaked/no lens)
820	100	10000	camera only (blaked/no lens)

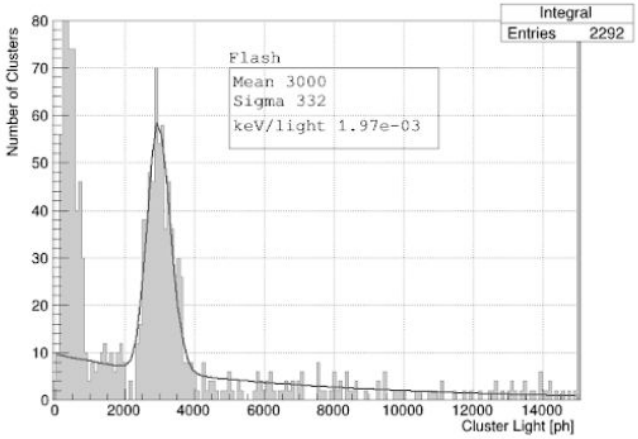
Sensor sensitivity (using ^{55}Fe)

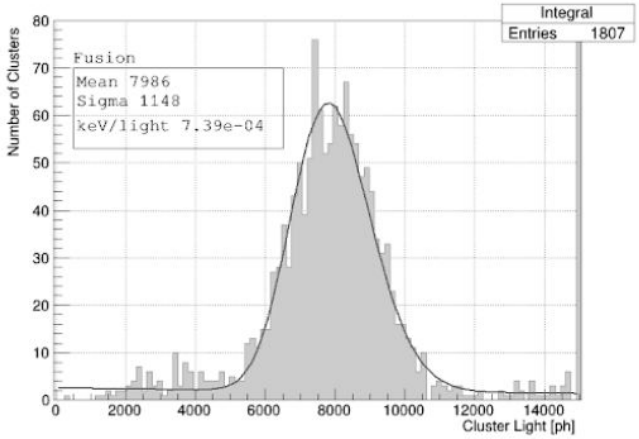
Fusion is the most sensitivity sensor with about 8000 of intensity for 5.9keV;

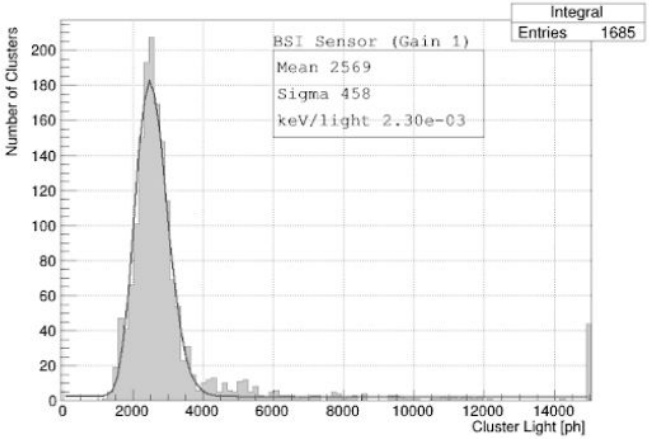
Energy resolutions:

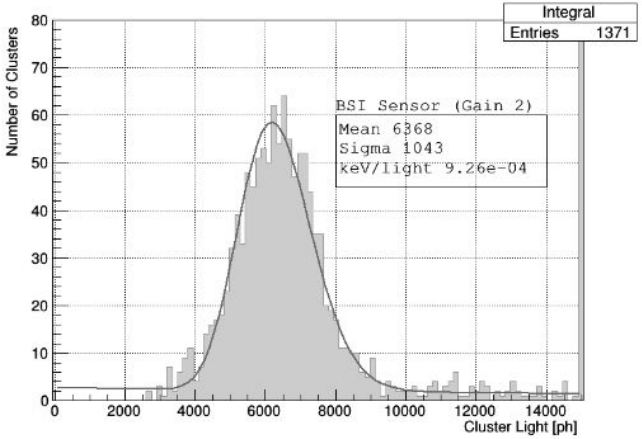
- Flash = 11.06%
- Fusion = 14.38%
- BSI_LG = 17.83%
- BSI_HG = 16.39

The clusterization algorithm has not been fully optimized for each one of the sensors.



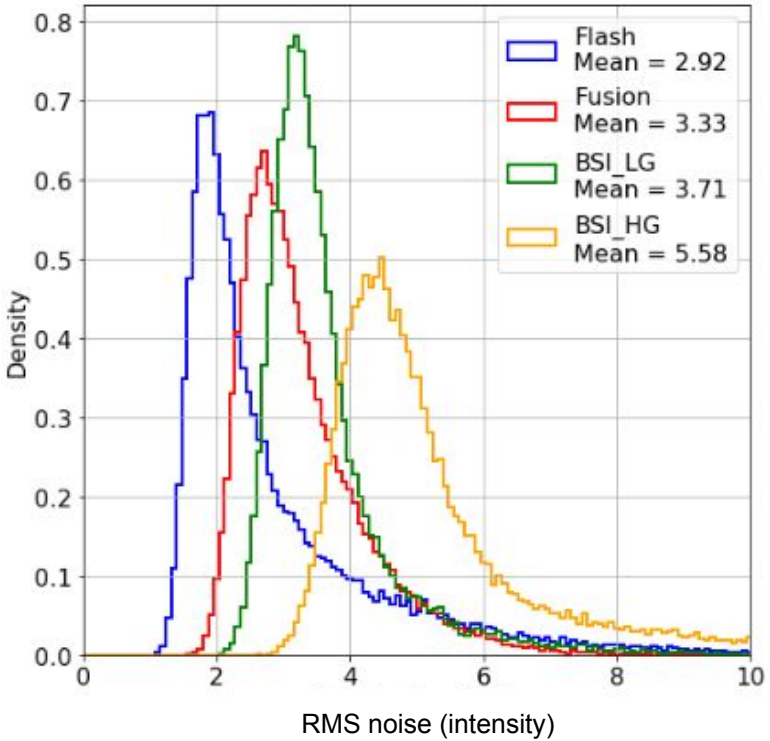


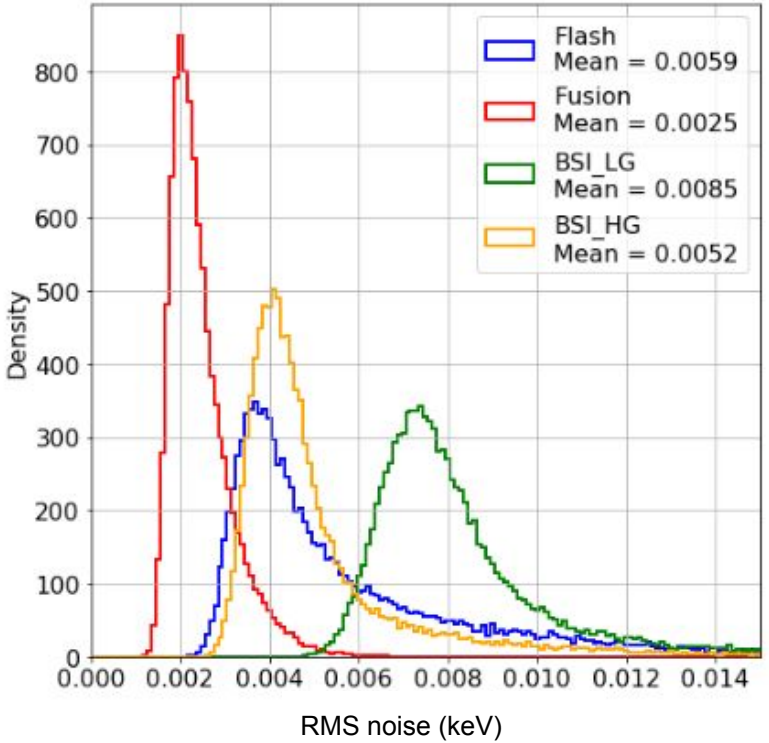




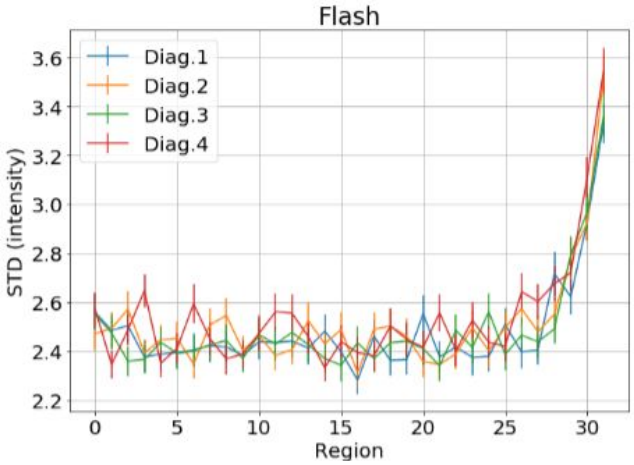
Sensor RMS noise

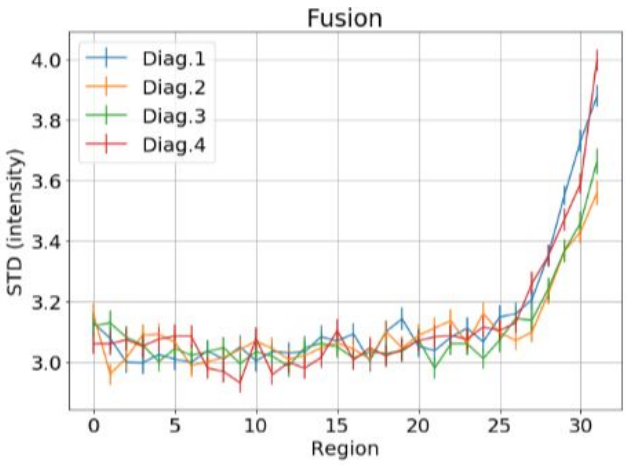
Fusion has the best noise performance in keV

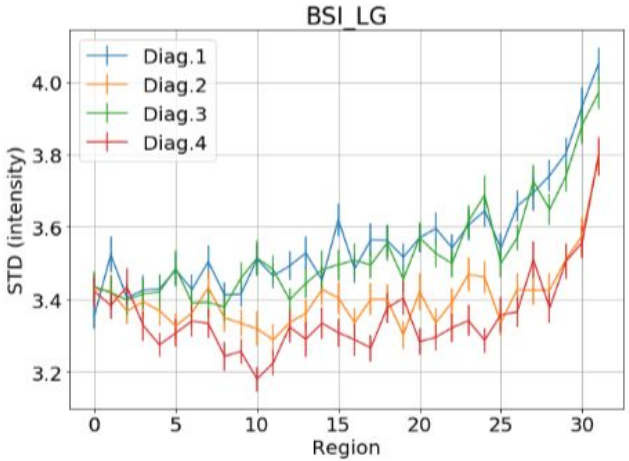


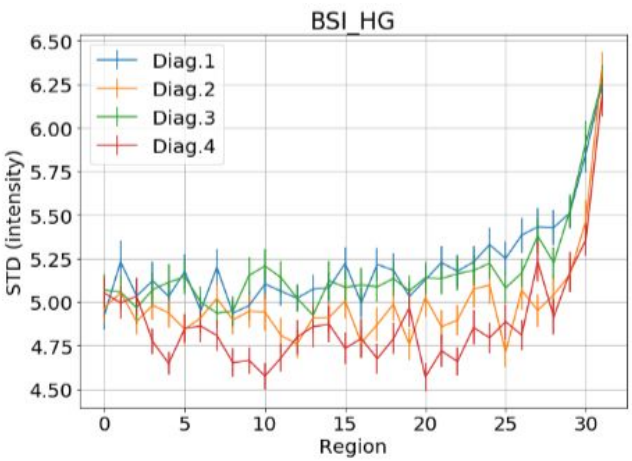


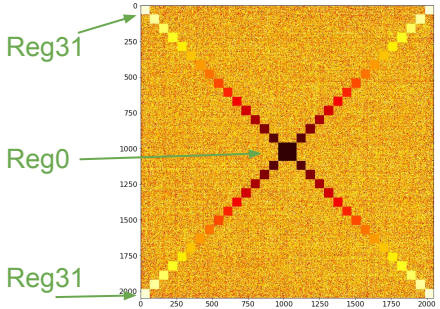
Sensor RMS noise (by region)









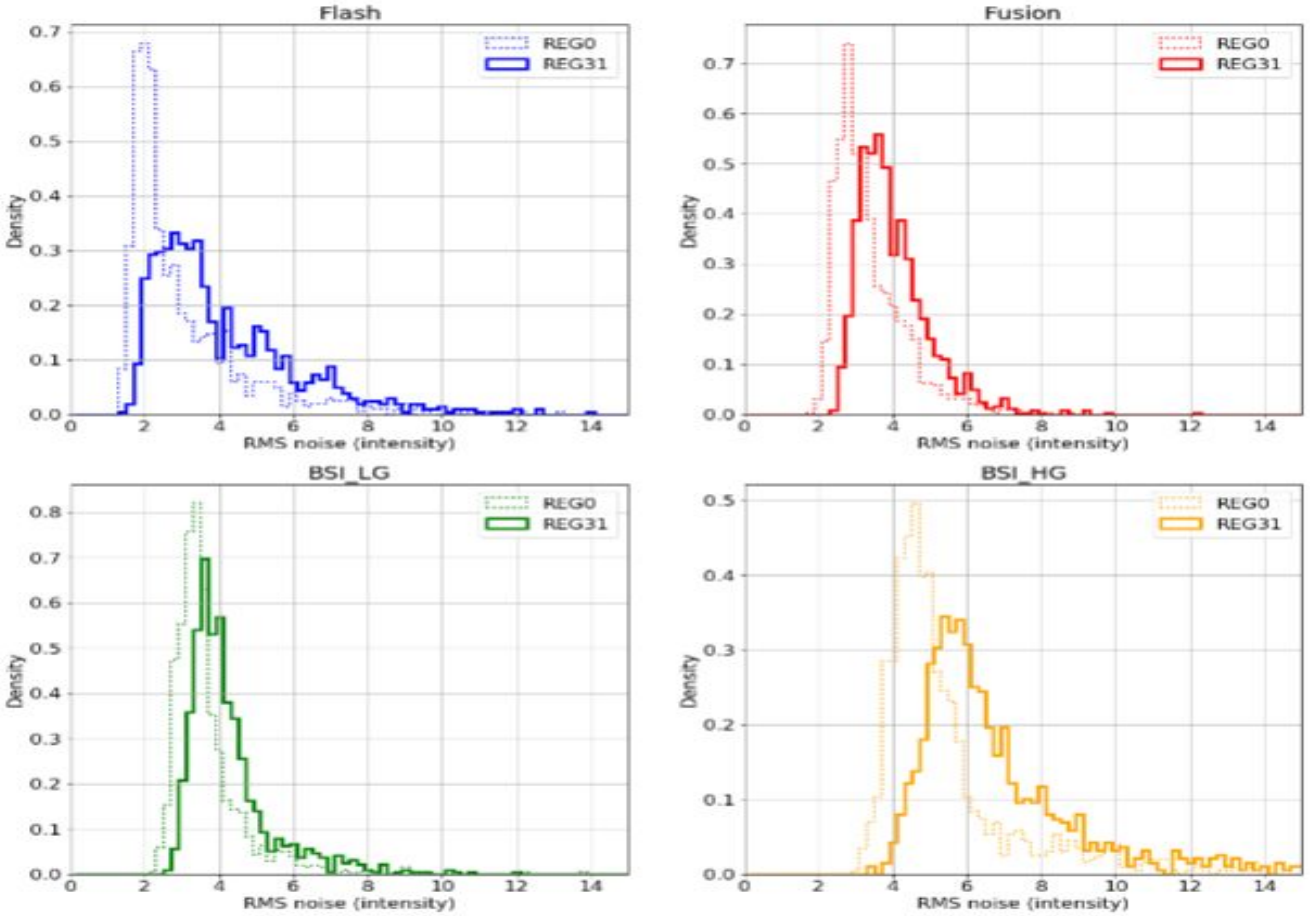


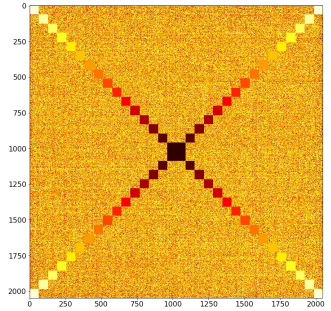
Each sensor has been divided into 4 diagonals and each of them into 32 regions

- Region 0 = center
- Region 31 = border limit

All sensors present border effect: noisier pixels on the borders

Sensor RMS noise (by region)

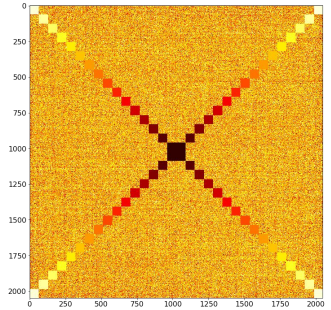




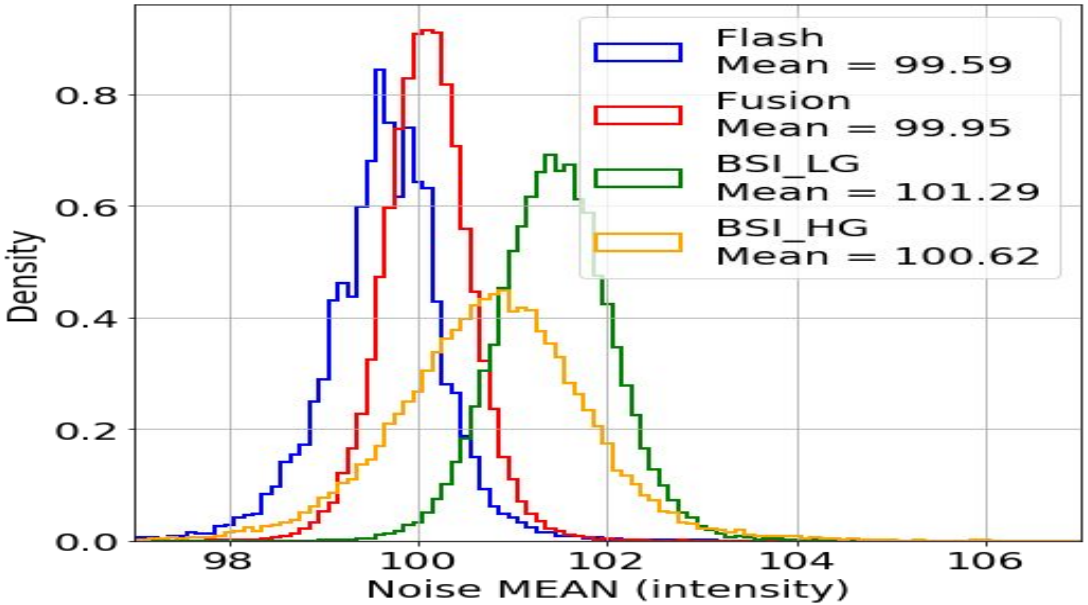
Comparing the two extreme regions:

- Region 0 = center
- Region 31 = border limit

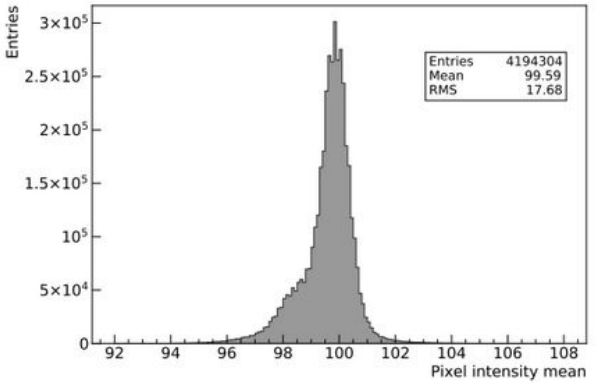
Sensor MEAN noise



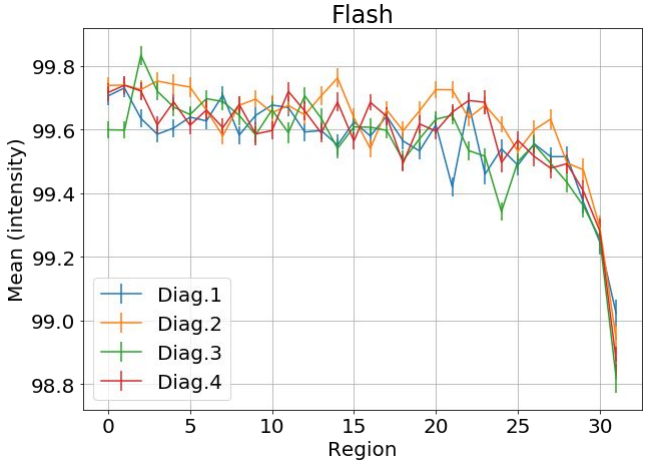
using only the selected pixels

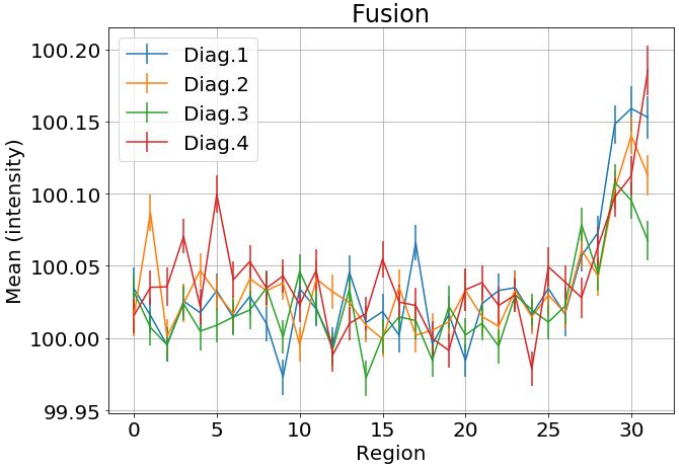


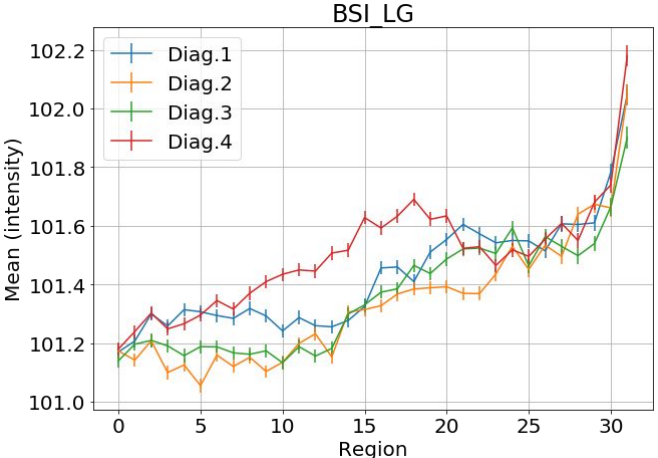
using all pixels (FLASH)

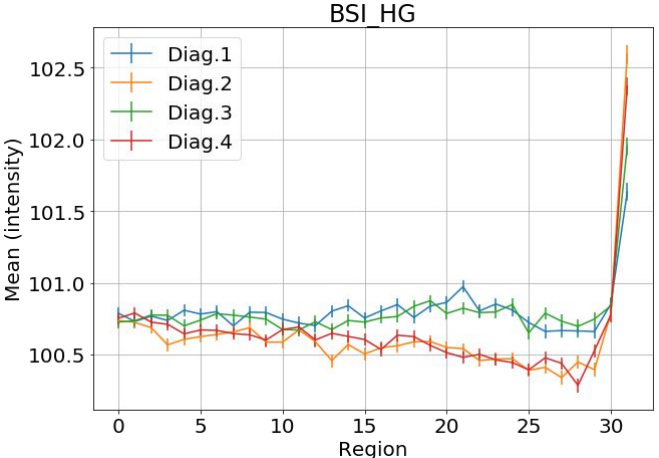


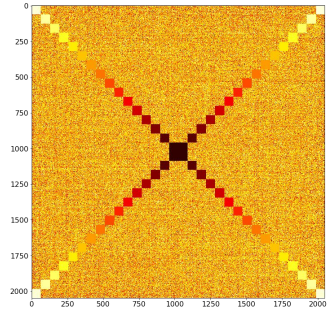
Sensor MEAN noise (by region)









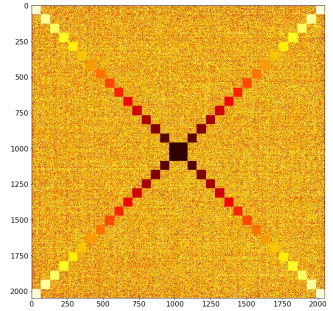


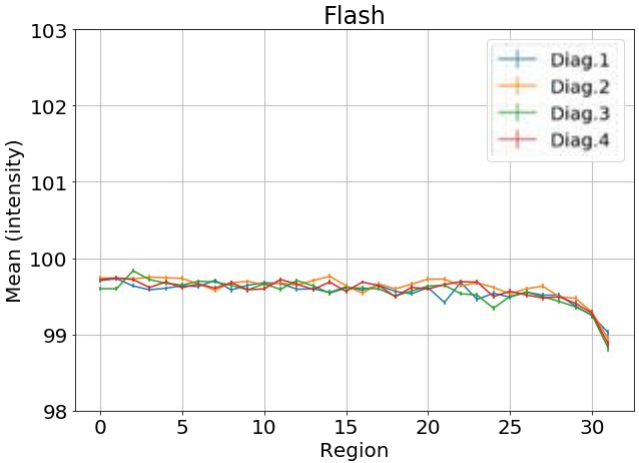
All sensors present border effect;

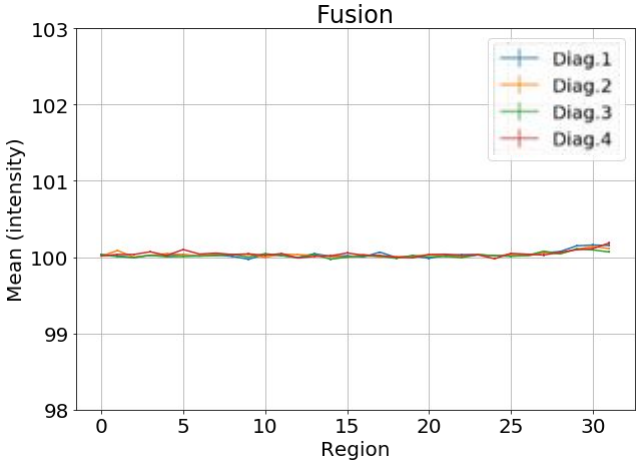
MEAN of Flash sensor decreases for the pixels at the border

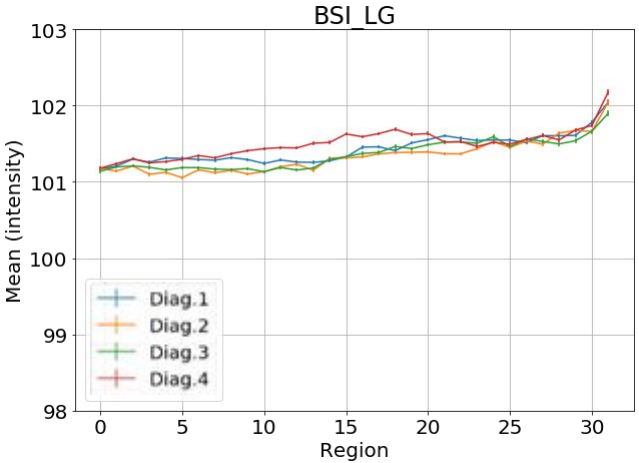
Sensor MEAN noise (by region)

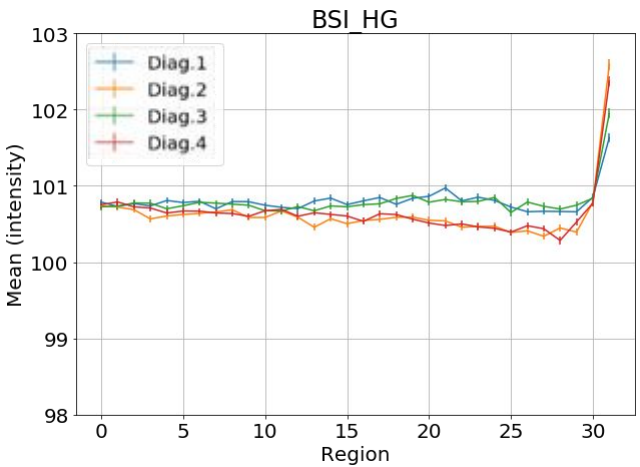
FIXED AXIS











MEAN of Fusion sensor varies less when compared to the other sensors

Nevertheless, it is not critical since pedestal subtraction is done pixel-by-pixel

Exposure time evaluation

STD and MEAN variation according to exposure time have been evaluated:

Flash sensor only for 10ms, 100ms, 1000ms and 10000ms

Used Runs:

File_Number	saved_events	Exposure_Time_ms	comments
3 ottobre 2018 Orca Flash black - no lens			
817	100	10	camera only (blaked/no lens)
818	100	100	camera only (blaked/no lens)
819	100	1000	camera only (blaked/no lens)
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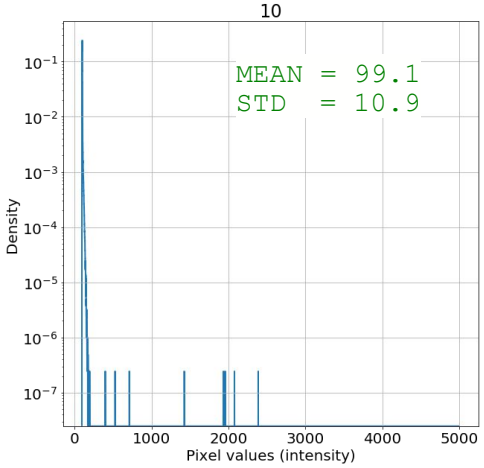
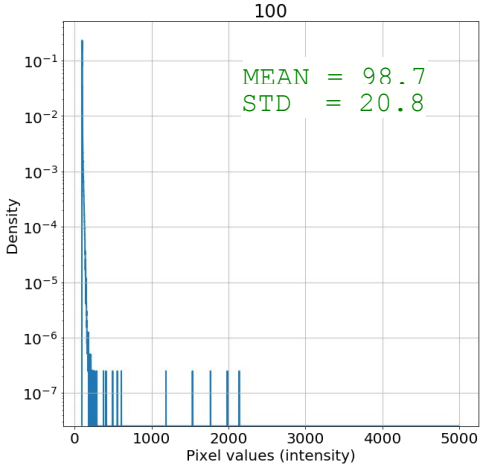
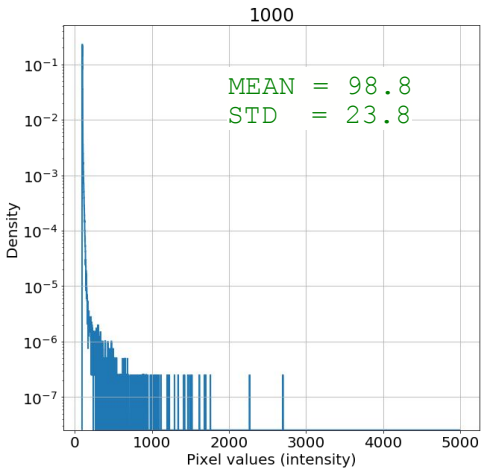
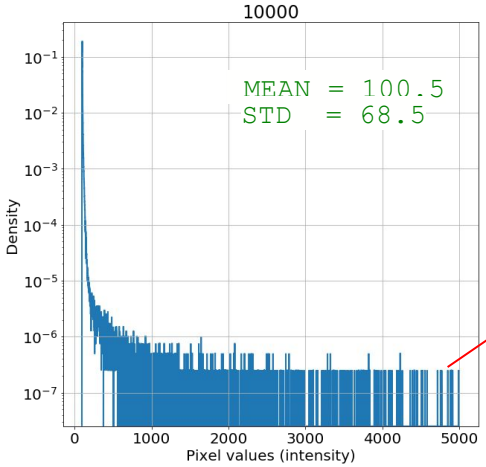
Exposure time evaluation



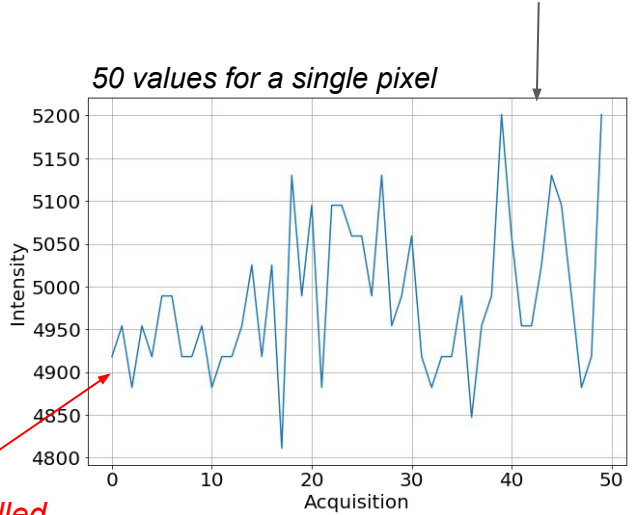






Longer the exposure time, greater is the number of pixels with very high values

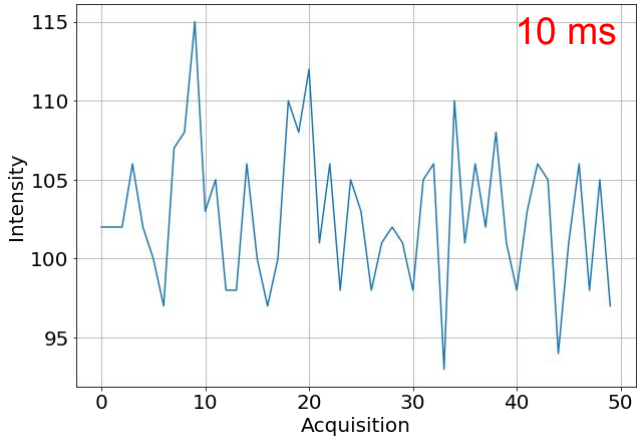
It seems that when a pixel goes high in intensity, it happens for all the images

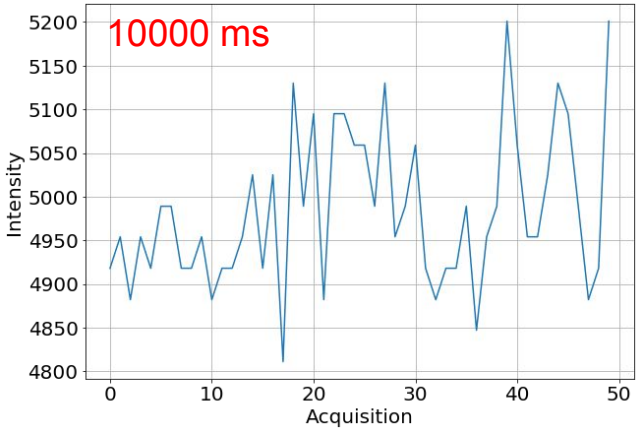


so called hot pixels

Exposure time evaluation

"Physically, these "warm/hot pixels" are mainly caused by charge leakages within the image sensor chip. Although the warm/hot pixels are randomly distributed within the chip, they are in a fixed position. Under normal conditions (shorter exposure times, normal light), many of them are not visible since their contribution to the general noise level is below this level."



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[107, 153, 622, 4918]
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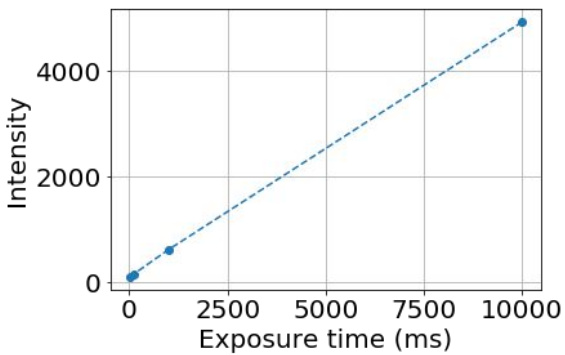
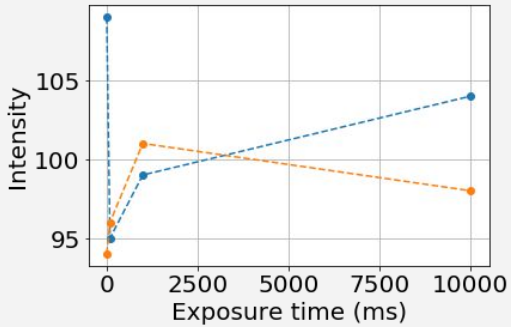


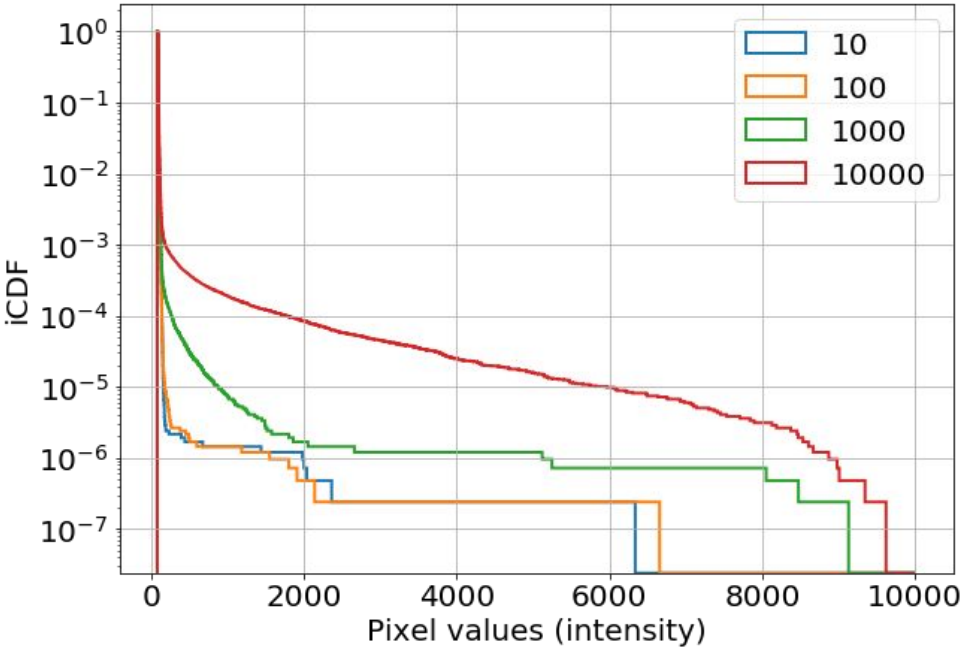
Some pixels increase in intensity when exposure time is increased

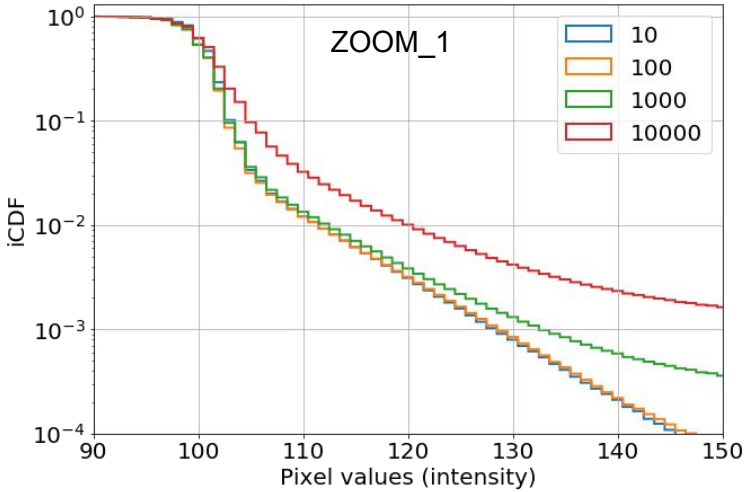


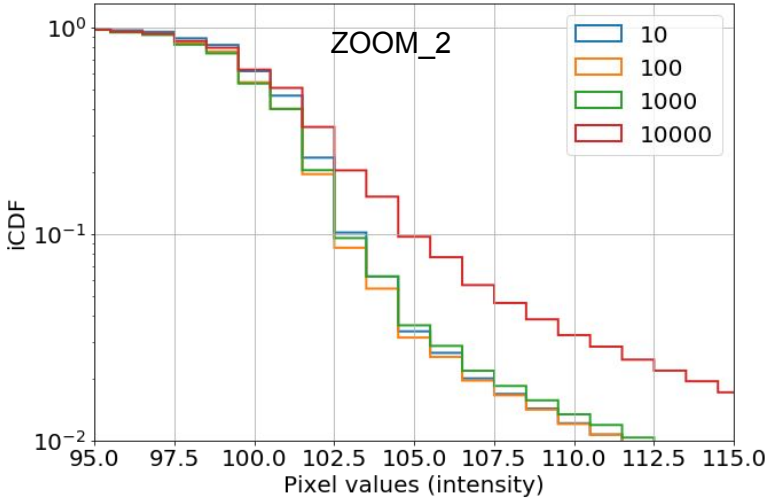
Example of 2 'good' pixels (intensity does not increase with exposure time)

Exposure time evaluation

- *iCDF shows how the intensity values increase for different exposure time.*
- *From 10 ms to 100 ms pixels values do not increase significantly*

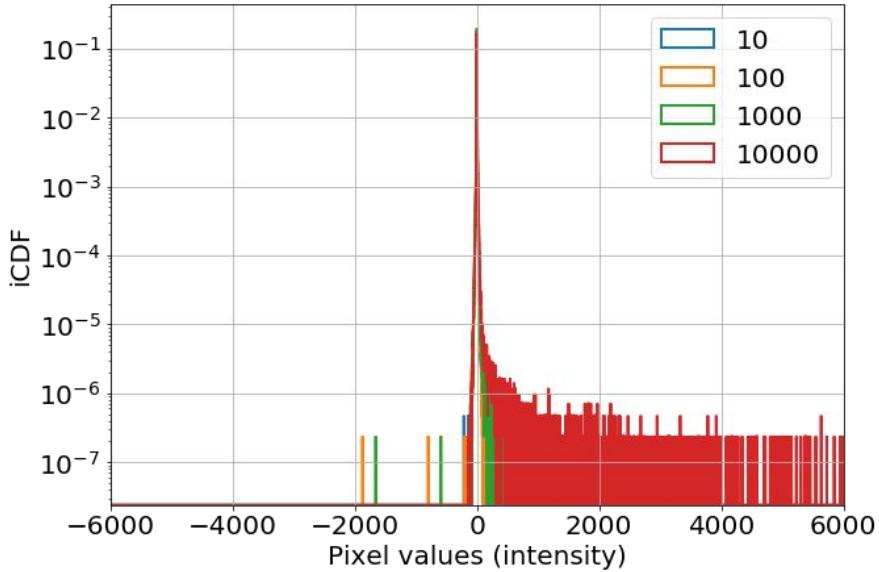




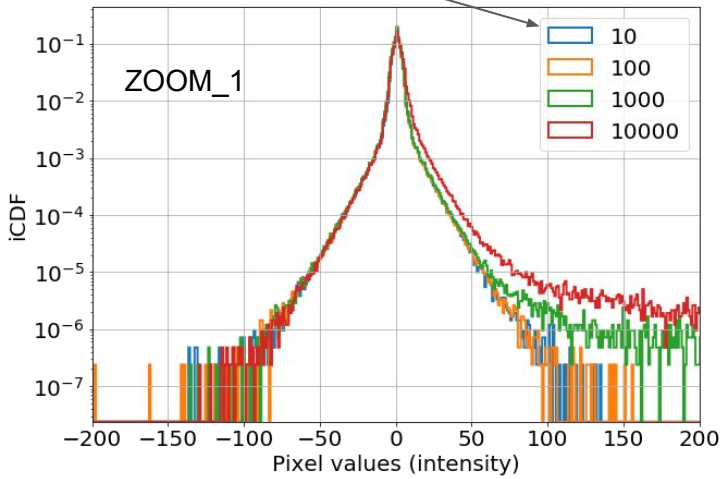


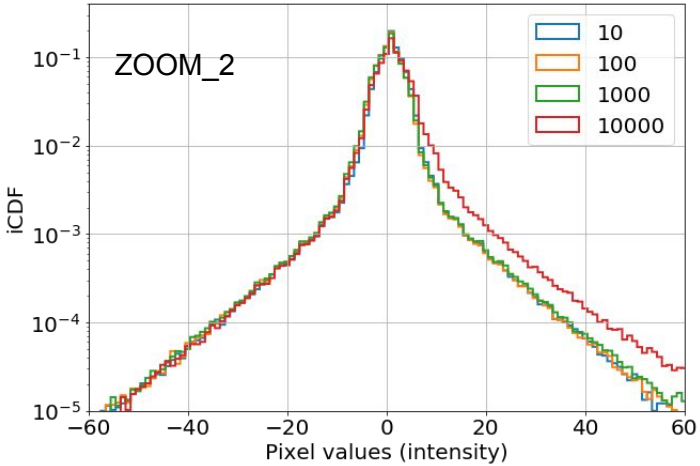
Exposure time evaluation

- *Subtraction between images → img{x ms} - img{10 ms}*
- *From 10 ms to 100 ms pixels values do not increase significantly*

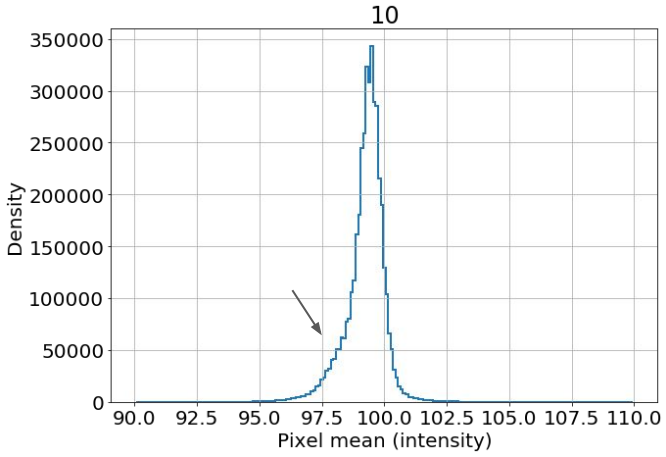


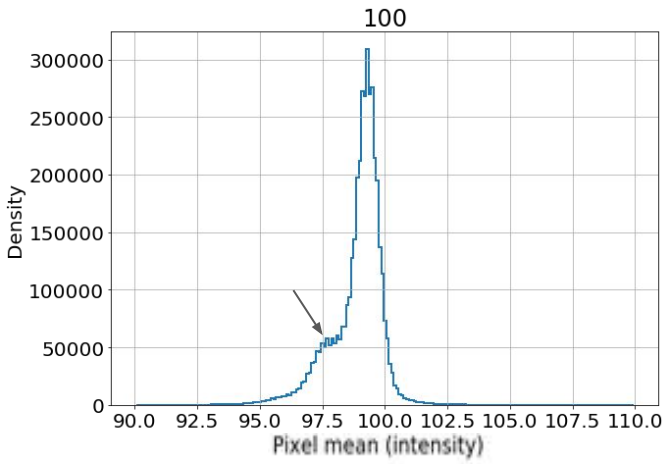
subtraction between two images from the same 10ms dataset

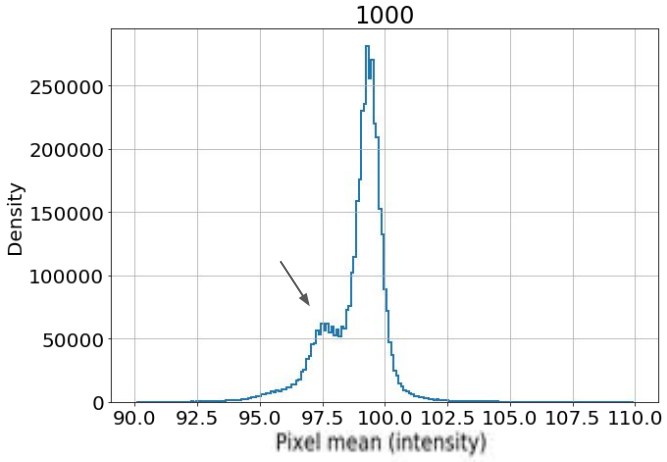


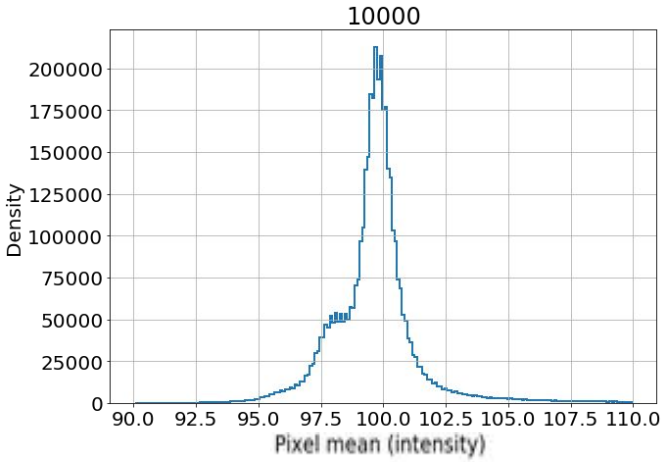


Exposure time evaluation (MEAN)



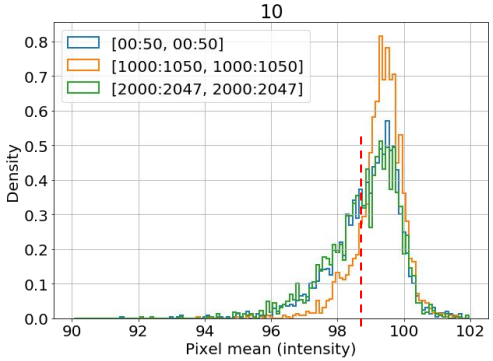


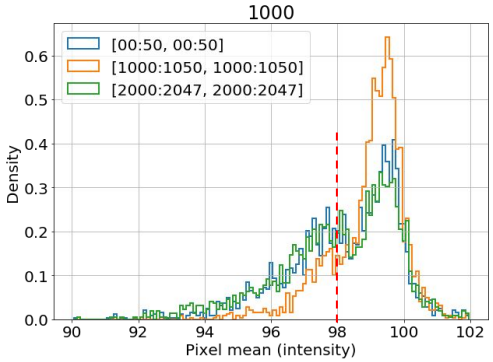




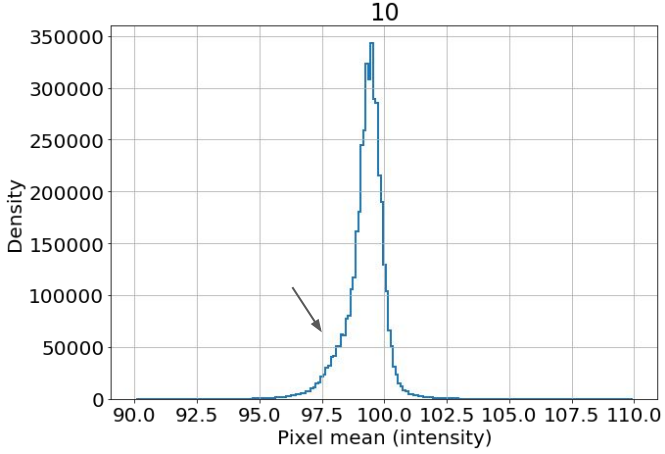
The longer the exposure time, the lower the intensity of the pixels located at the border of the chip

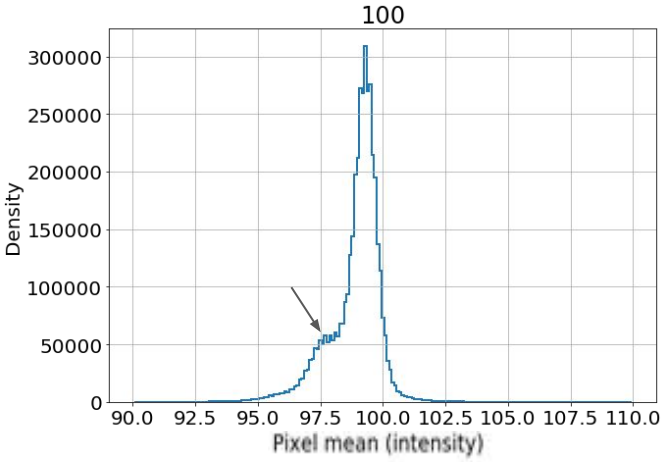
But also the center pixels contribute for the left bump

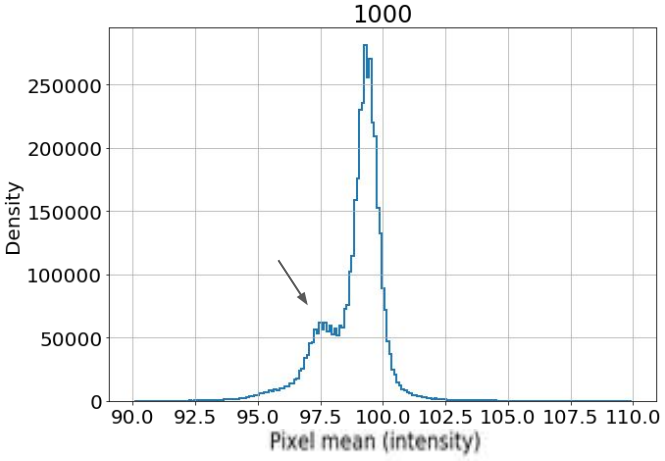


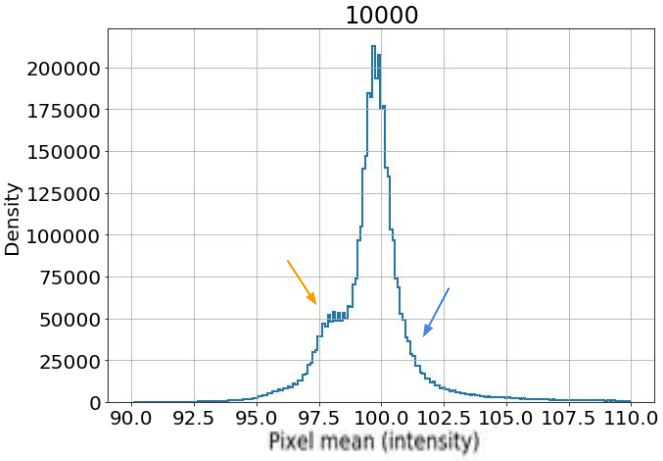


Exposure time evaluation (MEAN)

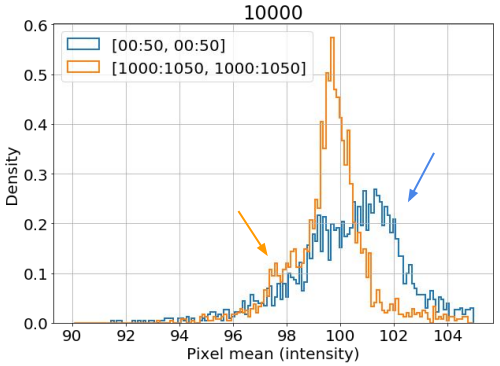




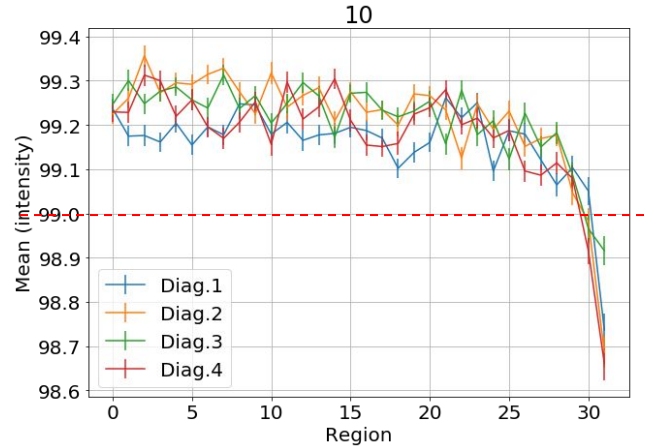


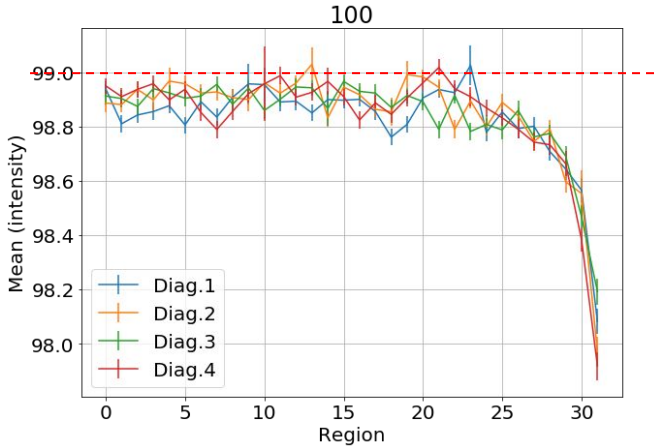


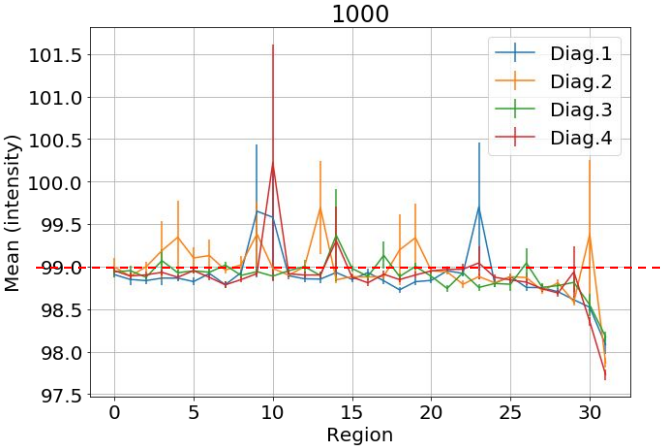
For the 10000 ms case, the right tail also gets bigger

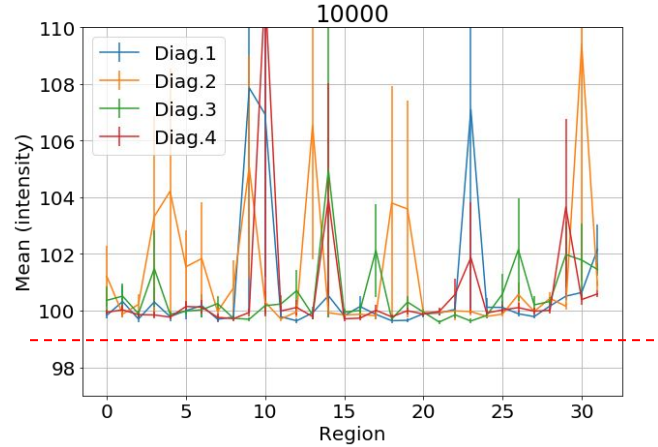


Exposure time evaluation (MEAN)









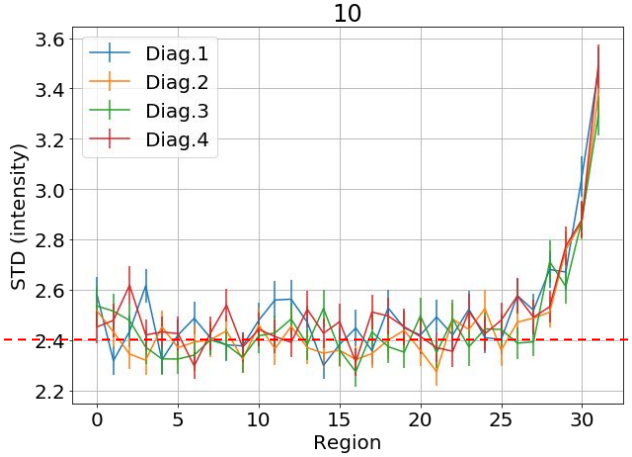
Overall MEAN oscillates around 99

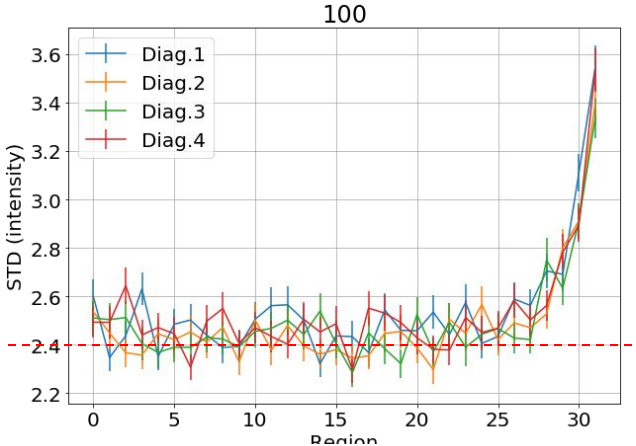
The border effect seems to be stronger for higher exposure times

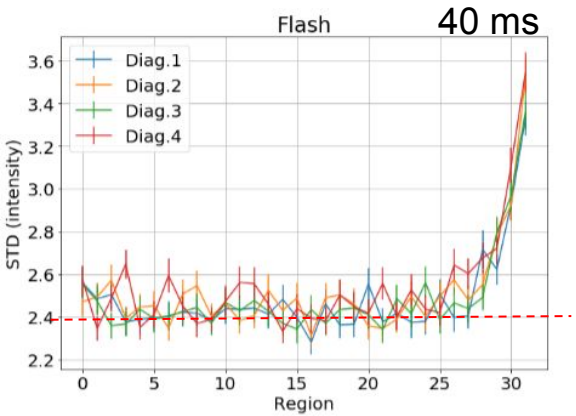
Above 1000 ms the number of hot pixels increase considerably, impacting on the MEAN values (sparks)

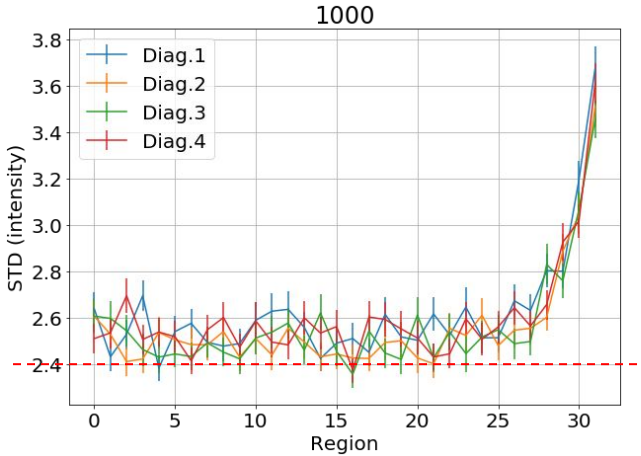
AND for 10000 ms the border pixels have their intensity MEAN rising (right tail)

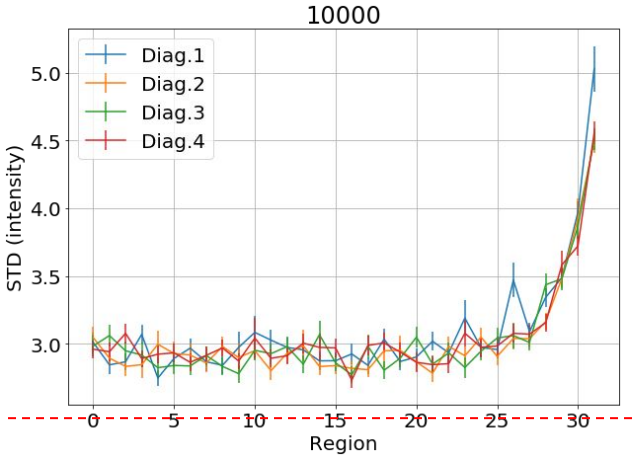
Exposure time evaluation (STD)











Overall noise begins to increase for 1000 ms

The border effect is significantly impacted only for 10000 ms

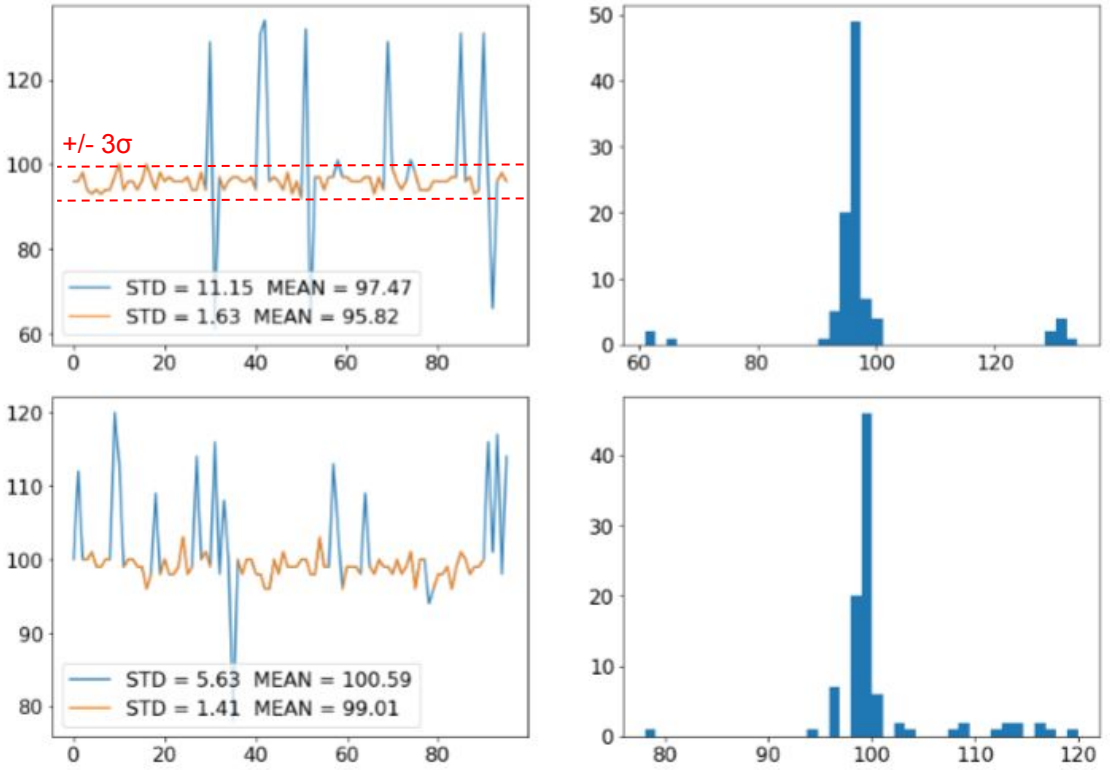
Random Telegraph Noise (RTN)

Long tail of the noise distribution is dominated by RTN;
https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5751670/

The right plots show the noise behavior of two pixels with RTN;

Every sample out of 3 sigma limit is excluded (in blue) and the STD ratio (before and after excluding such samples) is computed, called Correction Factor (CF)

Correction Factor (CF)
- CF = 11.15/1.63 = 6.8
- CF = 5.63/1.41 = 4.0

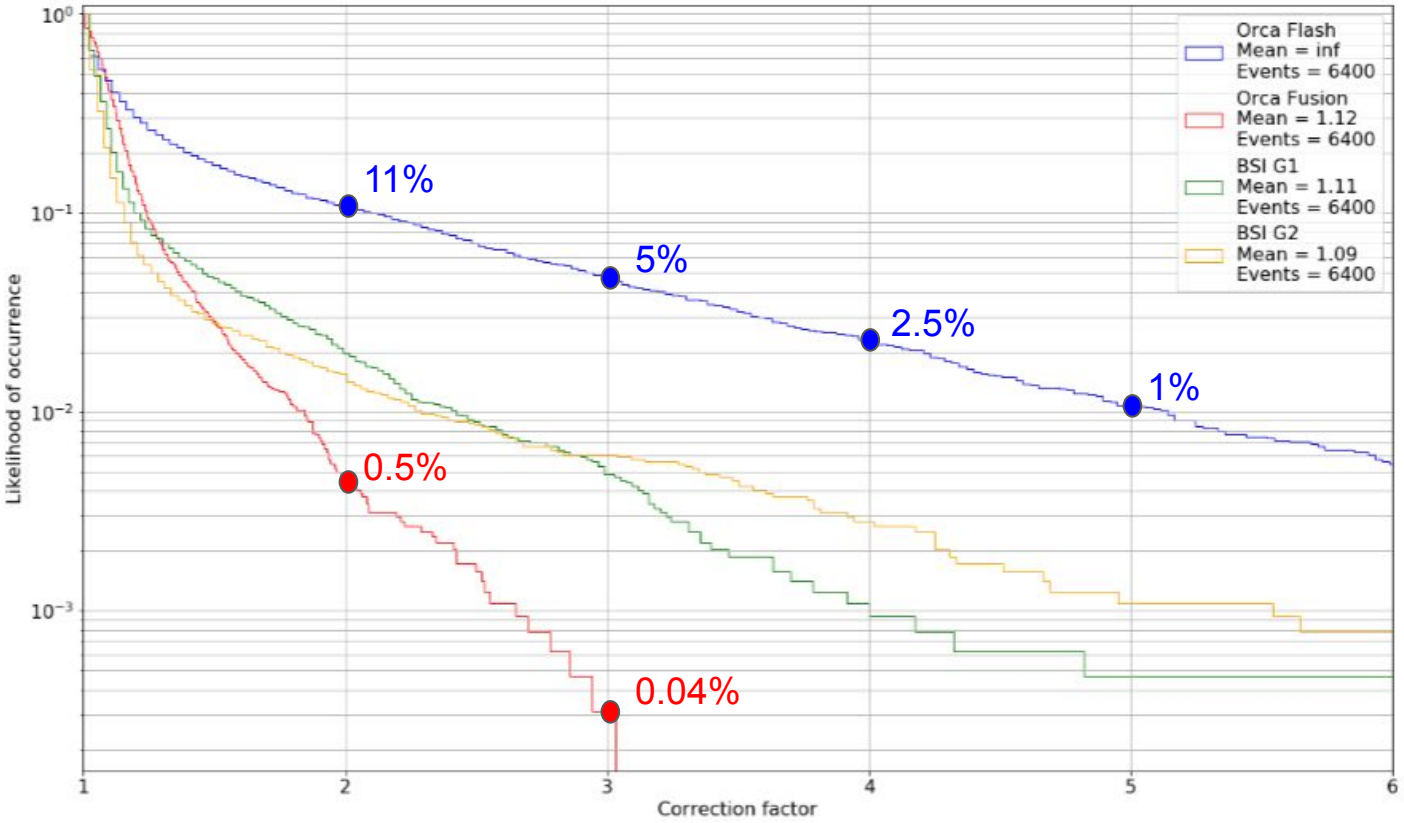


Random Telegraph Noise (RTN)

This plot shows the inverse CDF of the CF;

Flash sensor seems to have a high presence of RTN;
- 5% of pixels with a CF>3

Fusion sensor has the lowest number of pixels with RTN for CF>1.5;
- 0.04% of pixels with a CF>3



Conclusions

- Some noise characteristics have been measured for ‘4’ different sensors
  - The Fusion sensor seems to have the best characteristics
    - Best RMS noise, border effect and telegraph noise
  - The Flash sensor has high incidence of Telegraph Noise
- Exposure time has been evaluated for the Flash sensor
  - Above 1000 ms the impact on noise is not negligible
  - Between 100 ms and 1000 ms we do not know what happens

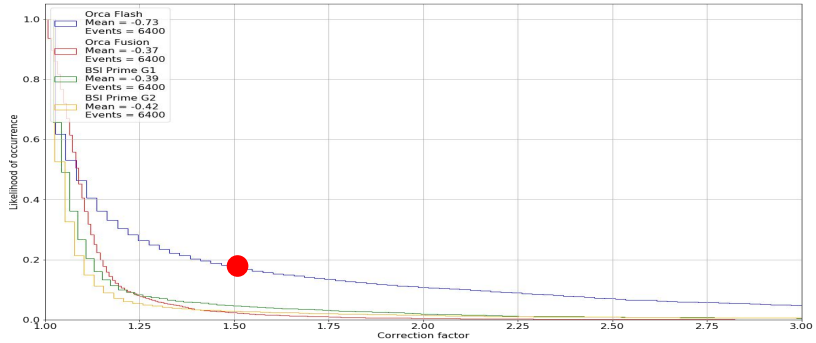
- We see a possibility for a paper (already started), but some issues, as exposure time, have no enough acquisitions for all the sensors

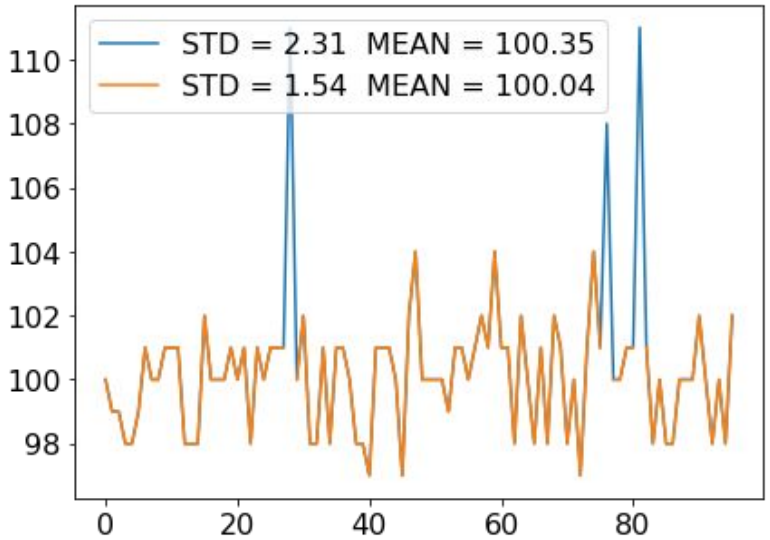
Back-up

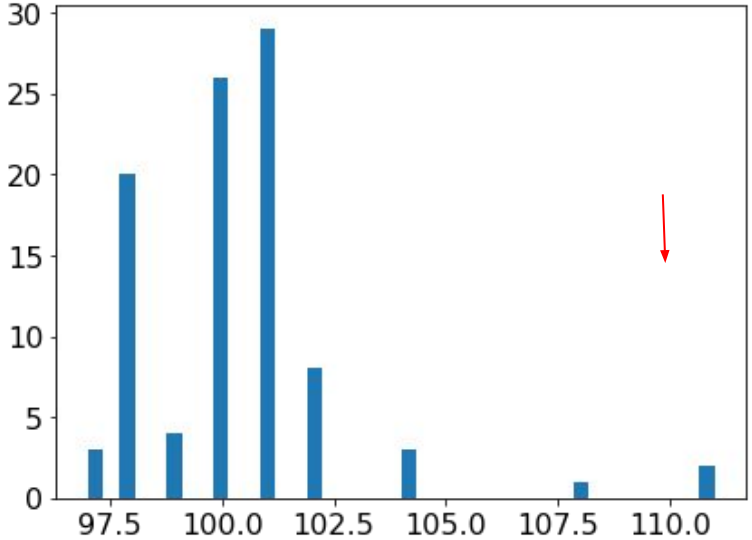
RTN examples for the Flash and Fusion sensors

Flash CF~1.5

STD_{normal} / $STD_{clipped}$

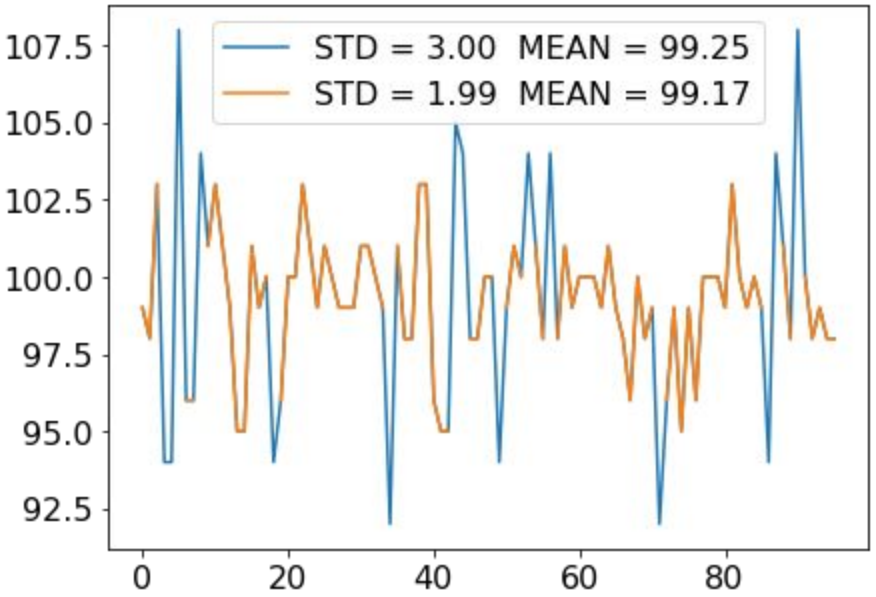


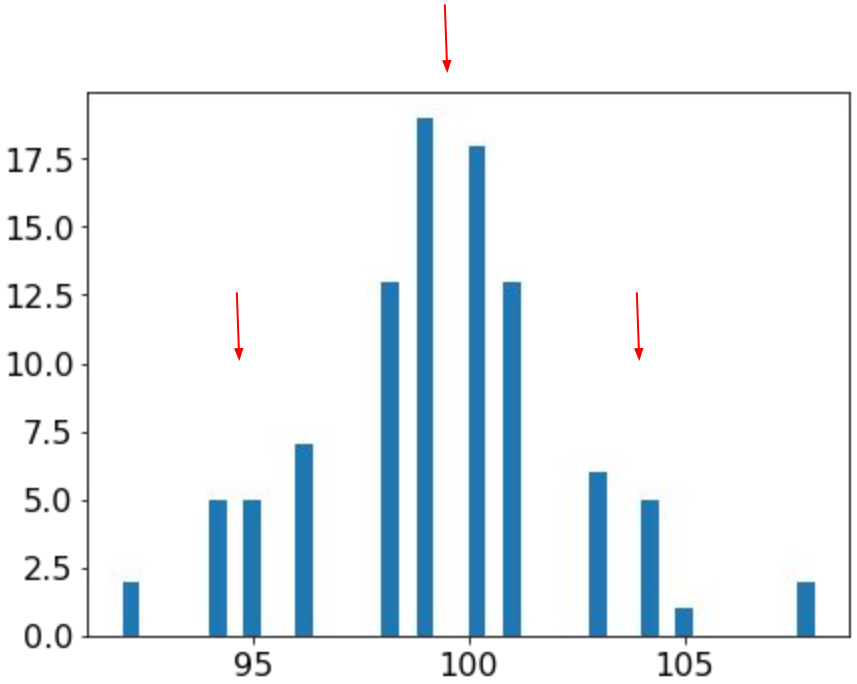




Flash CF~1.5

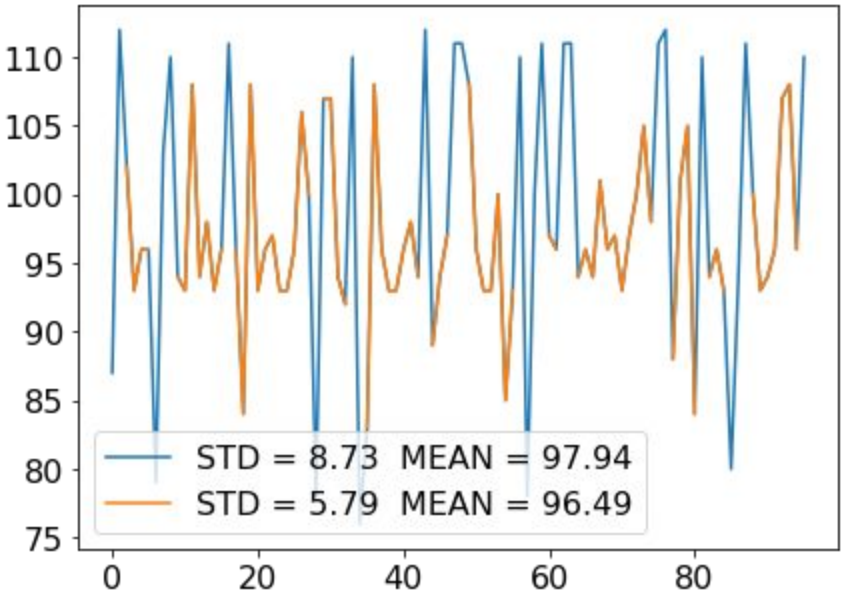
STD_{normal} / $STD_{clipped}$

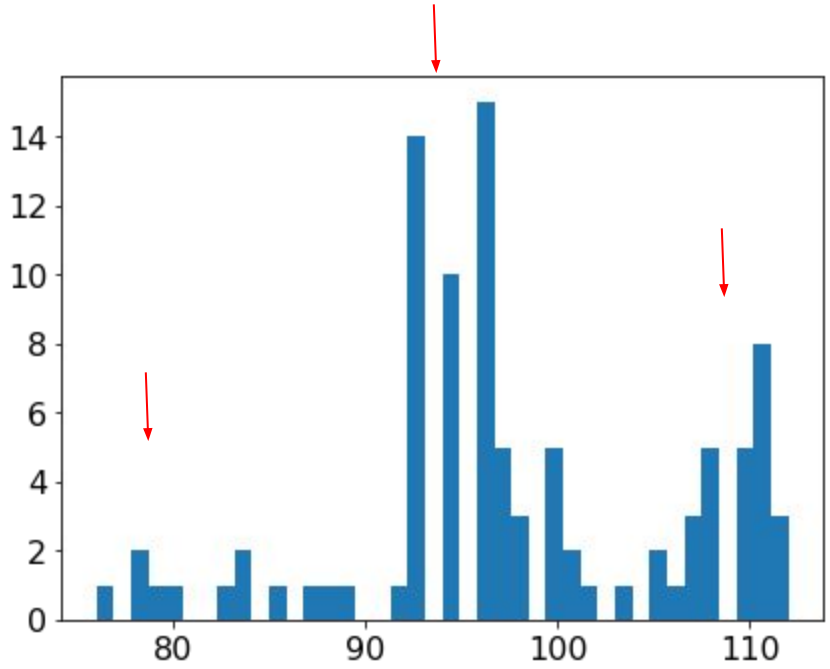




Flash CF~1.5

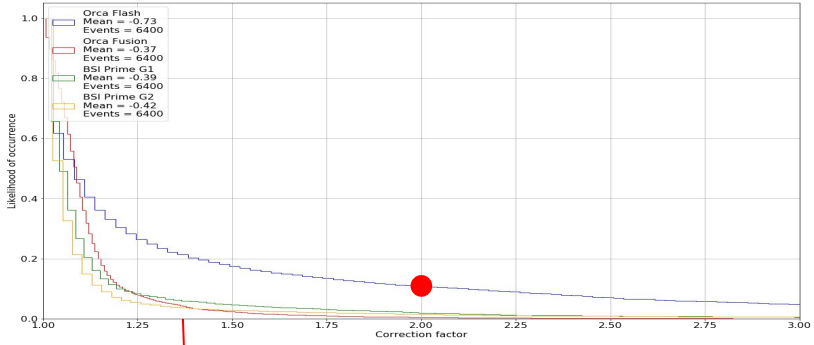
STD_{normal} / $STD_{clipped}$

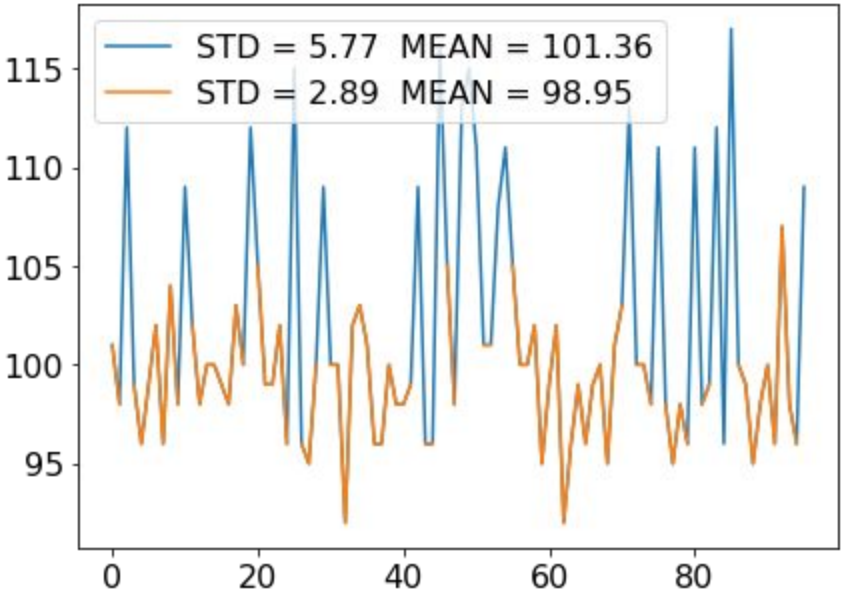


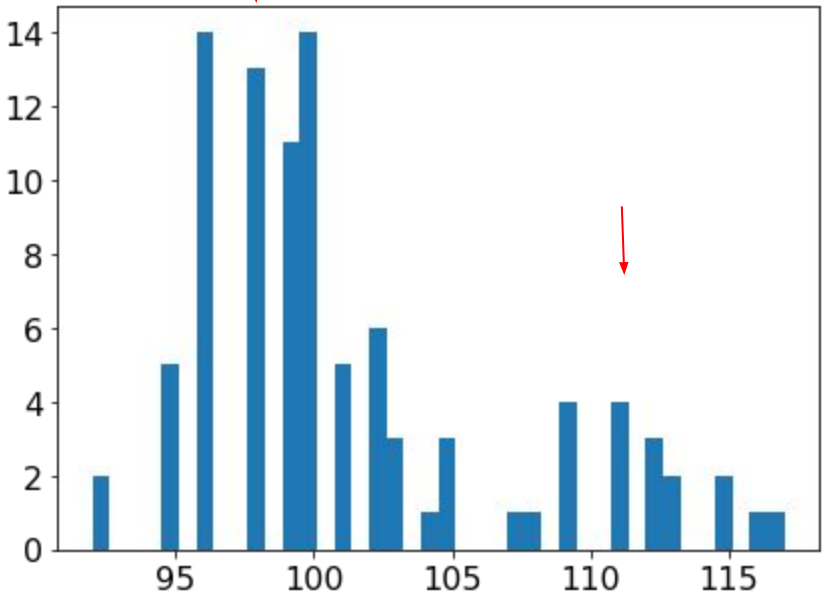


Flash CF~2.0

STD_{normal} / $STD_{clipped}$

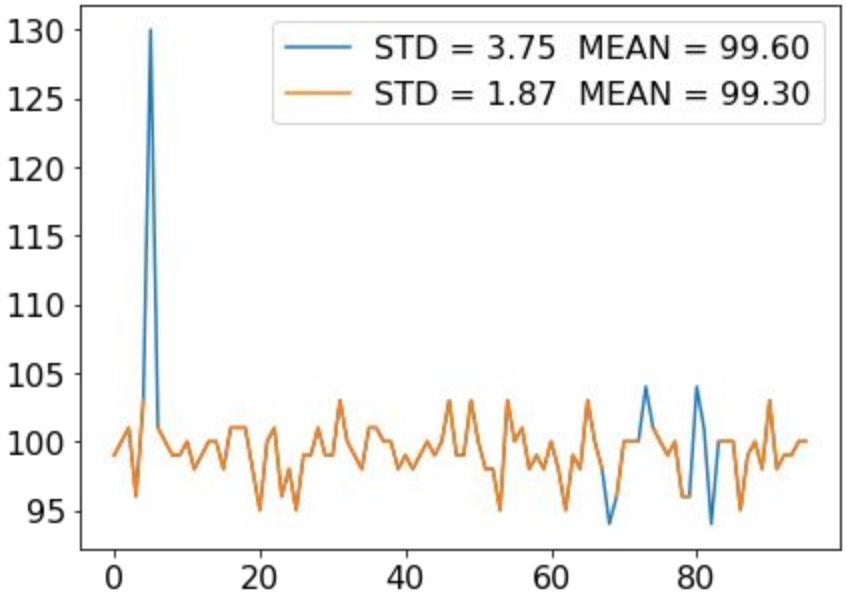


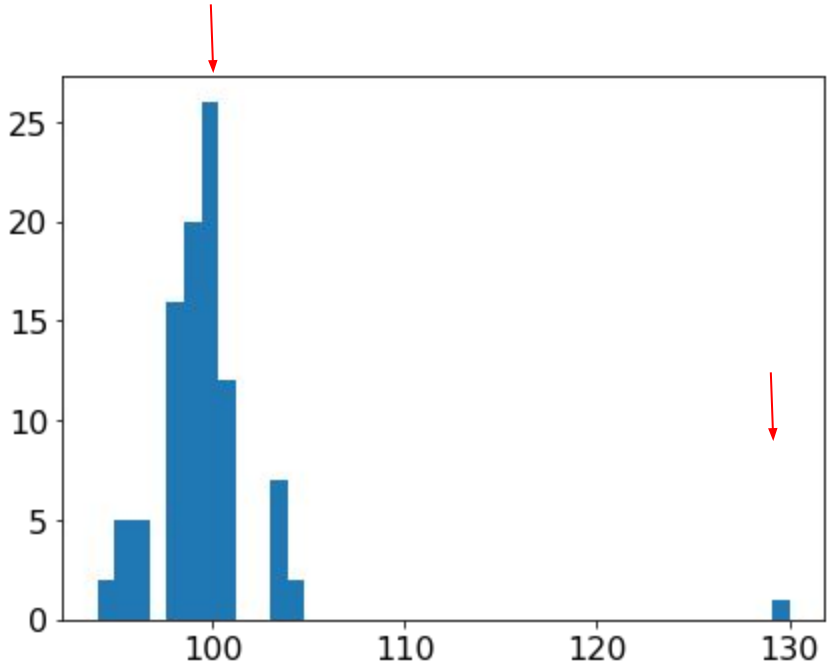




Flash CF~2.0

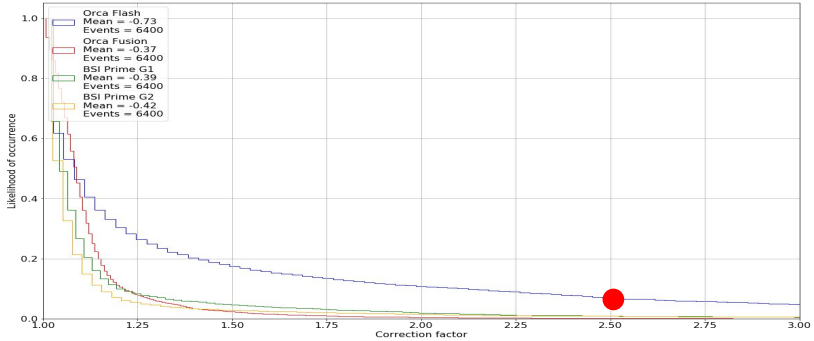
STD_{normal} / $STD_{clipped}$

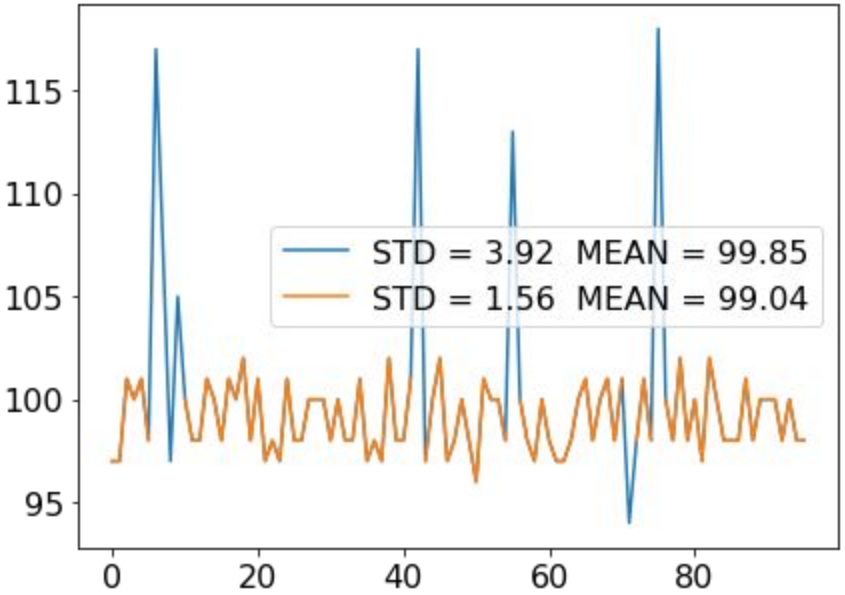


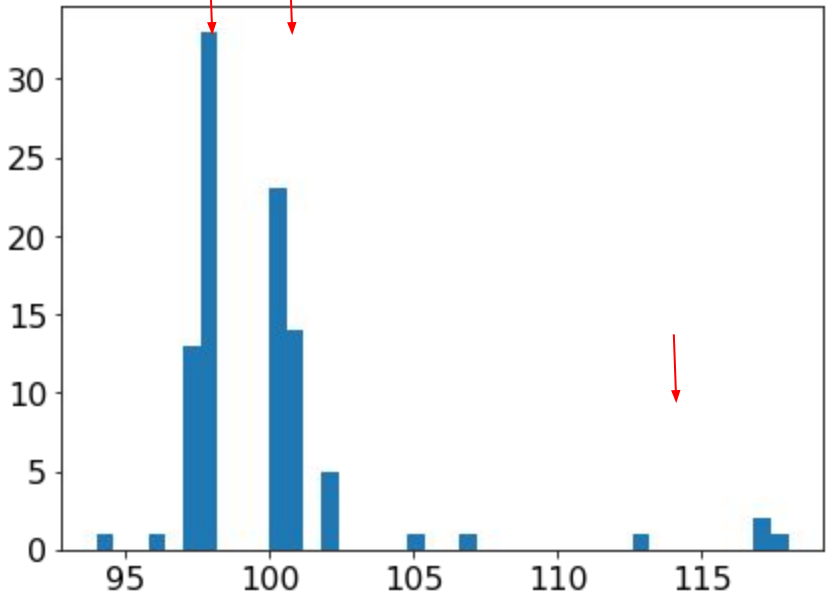


Flash CF~2.5

STD_{normal} / $STD_{clipped}$

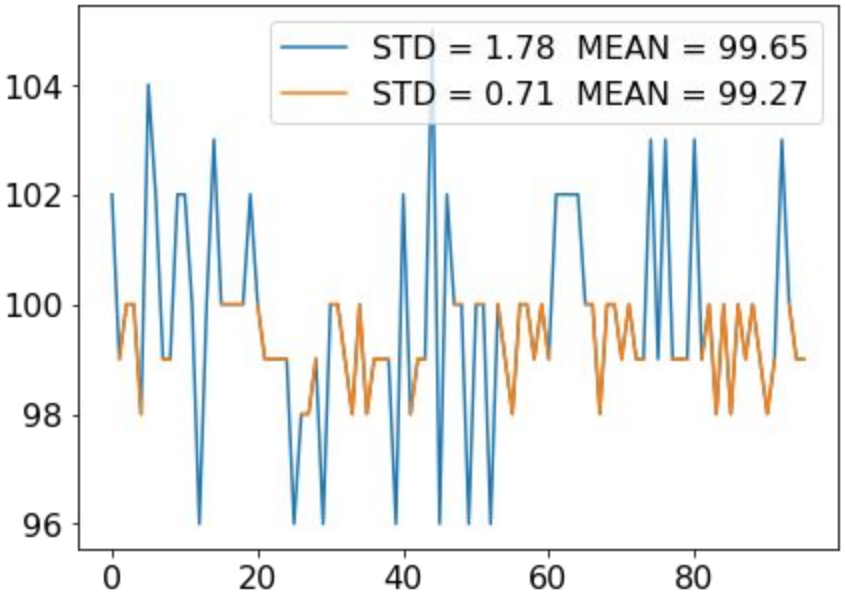


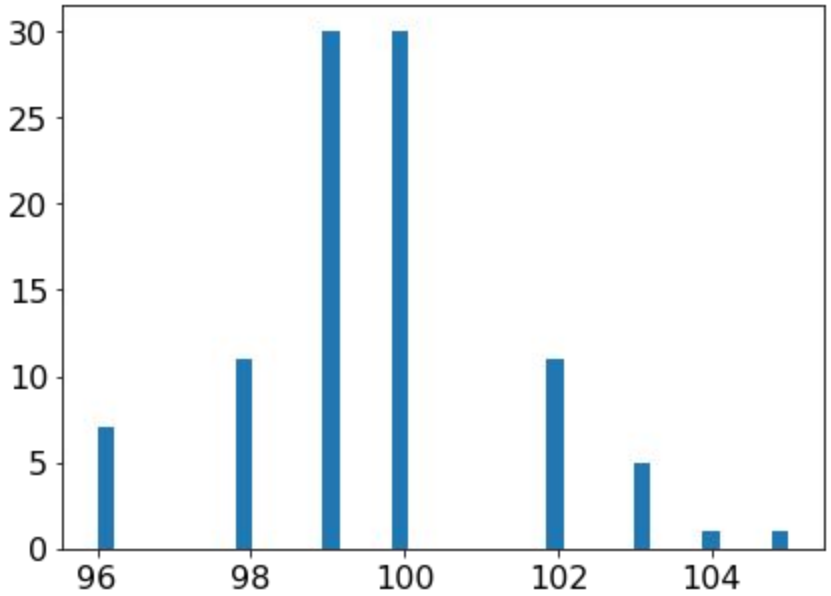




Flash CF~2.5

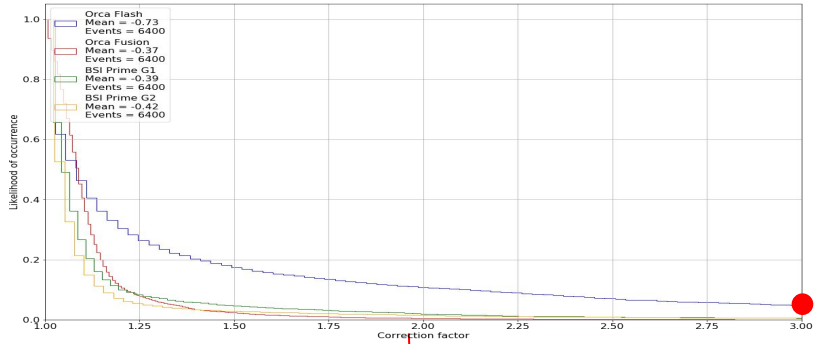
STD_{normal} / $STD_{clipped}$

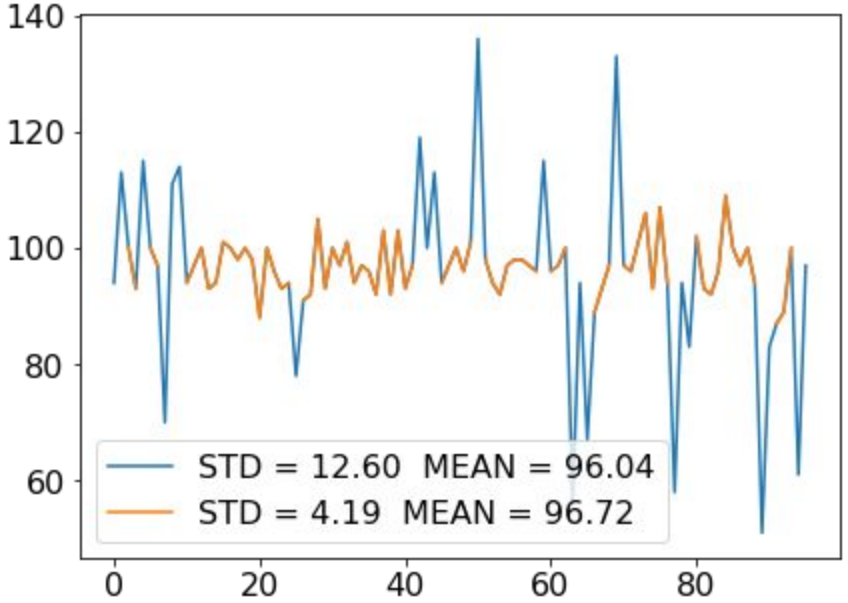


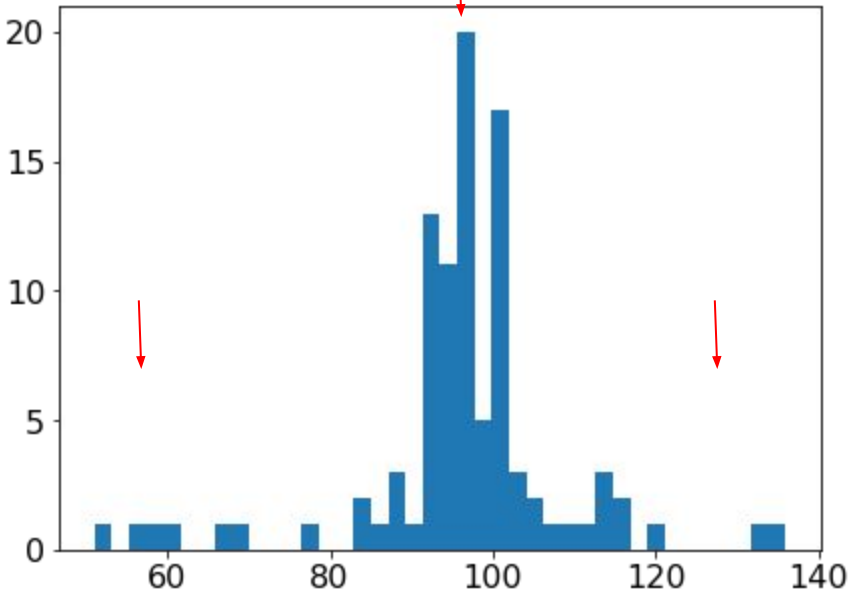


Flash CF~3.0

STD_{normal} / $STD_{clipped}$

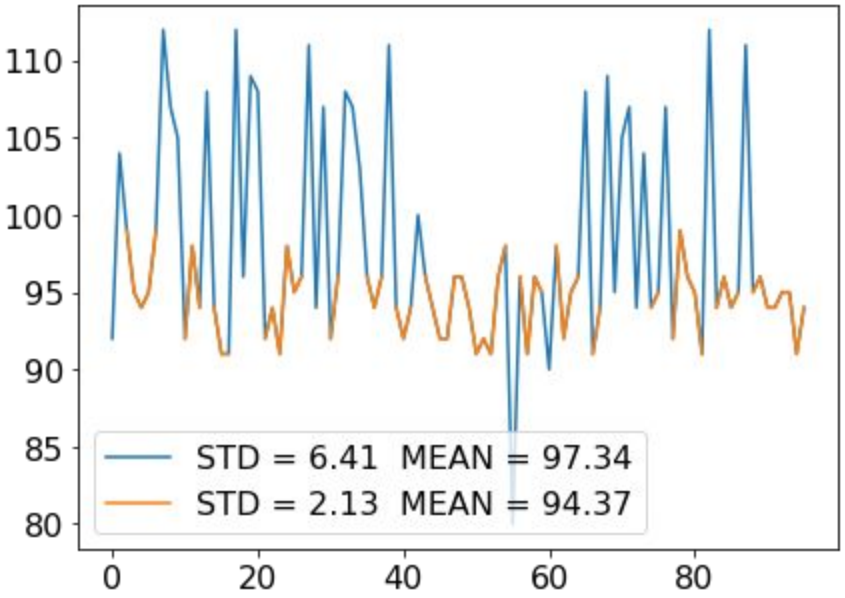


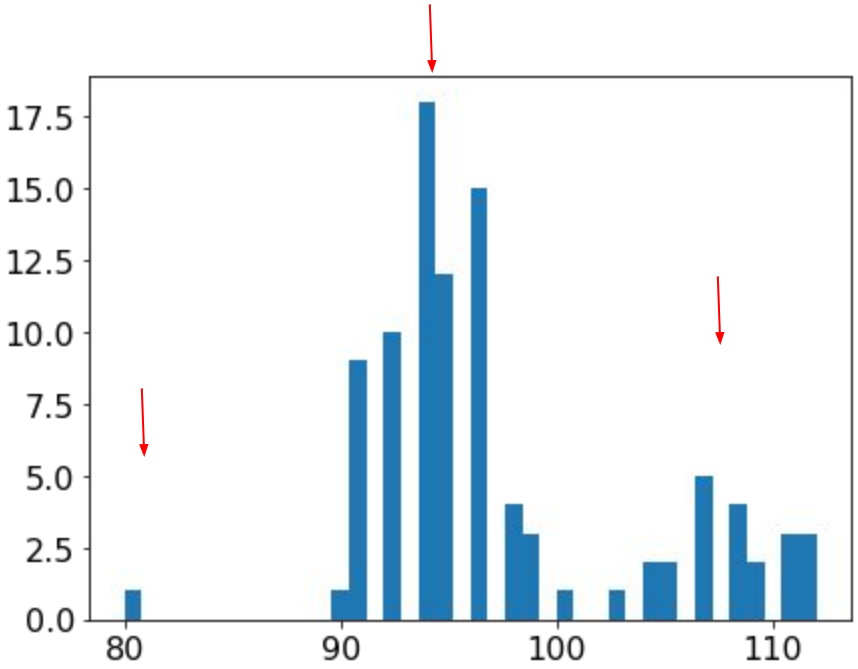




Flash CF~3.0

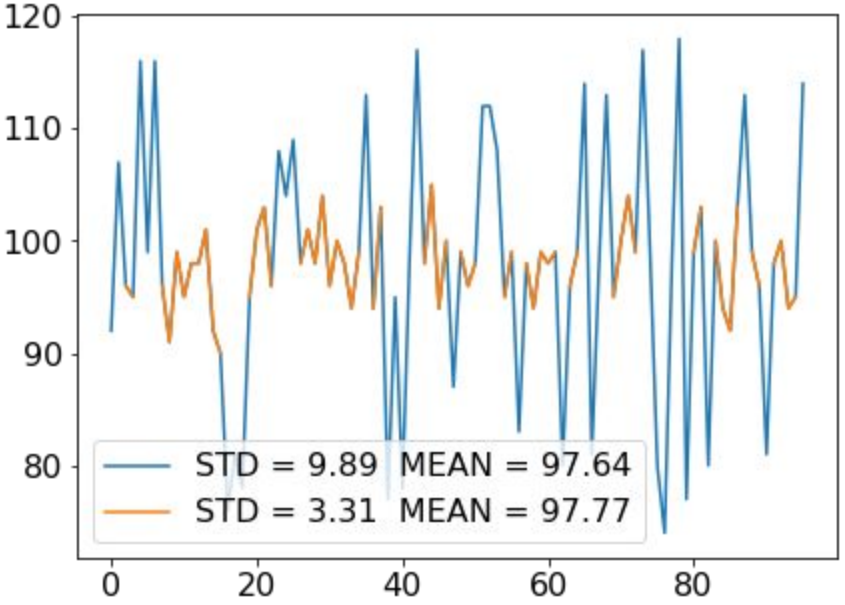
STD_{normal} / $STD_{clipped}$

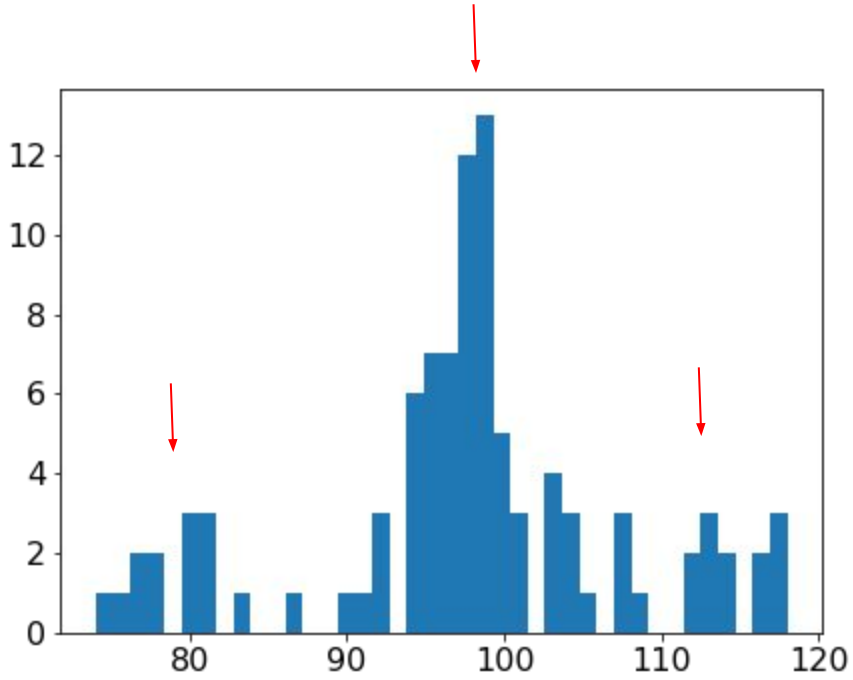




Flash CF~3.0

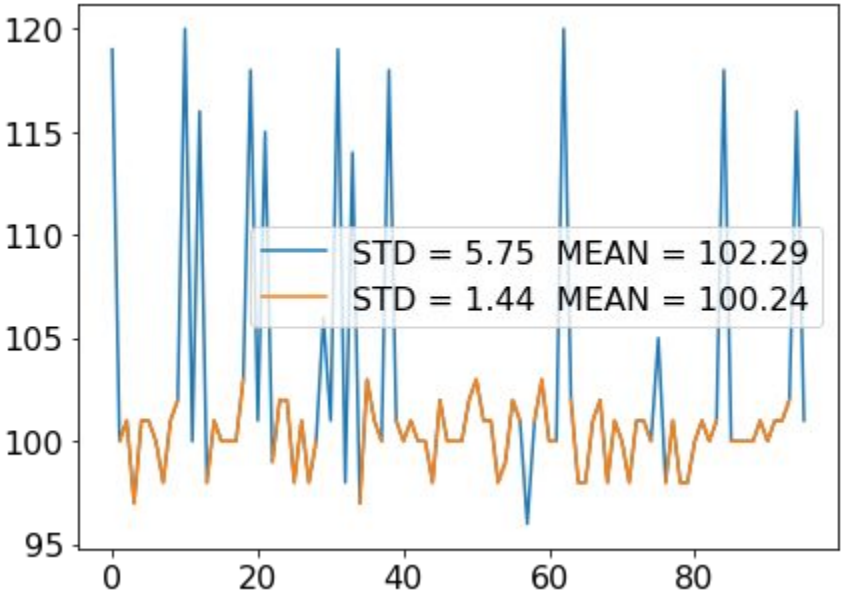
STD_{normal} / $STD_{clipped}$

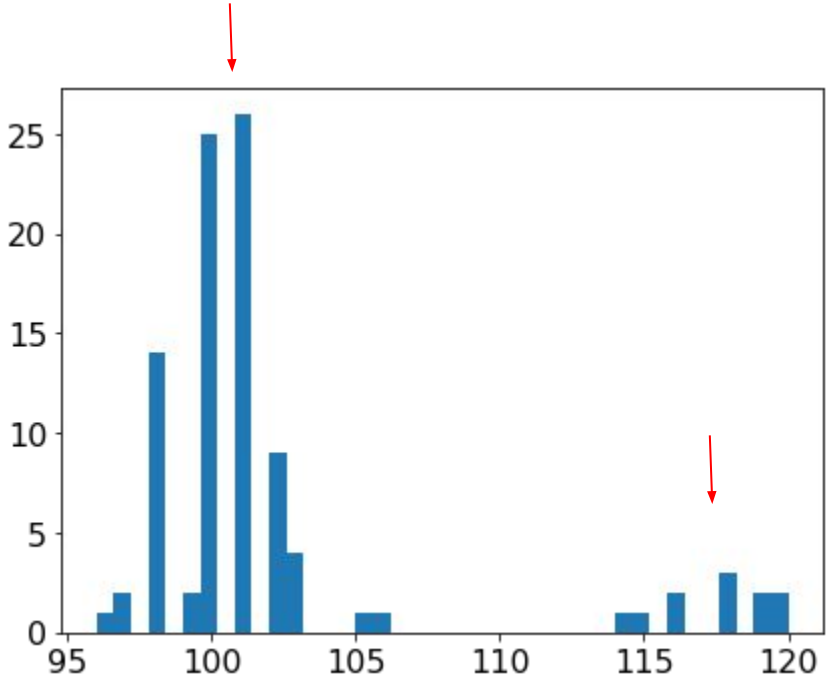




Flash CF~4.0

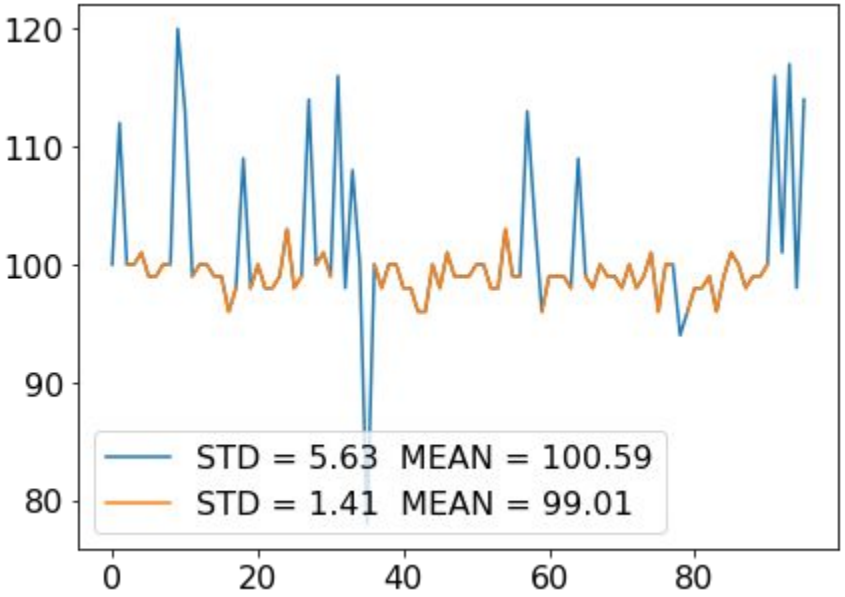
STD_{normal} / $STD_{clipped}$

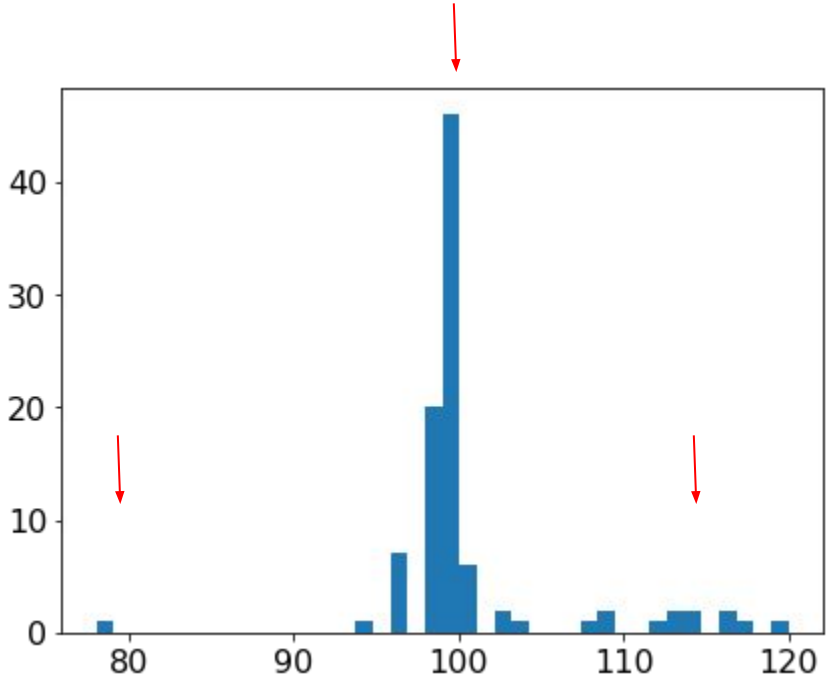




Flash CF~4.0

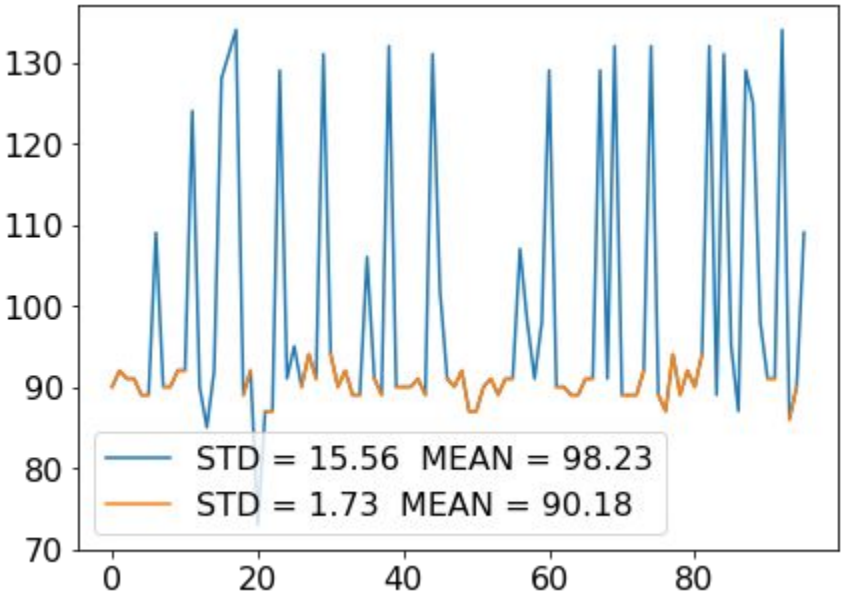
STD_{normal} / $STD_{clipped}$

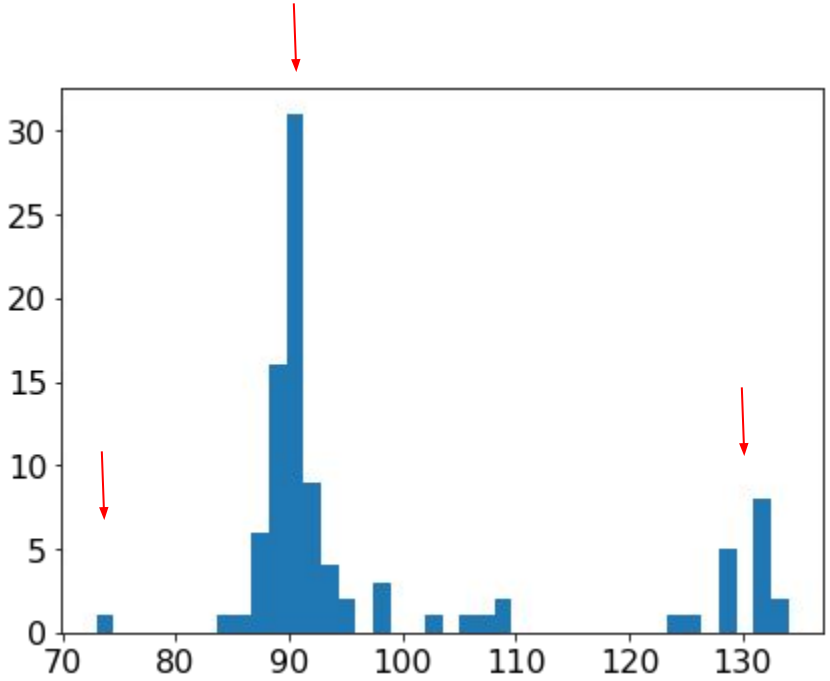




Flash CF>6.0

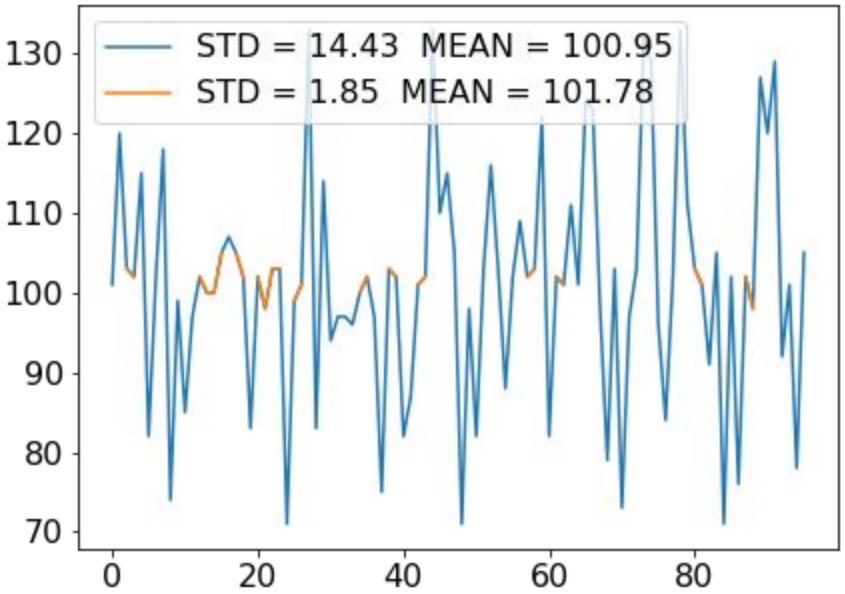
STD_{normal} / $STD_{clipped}$

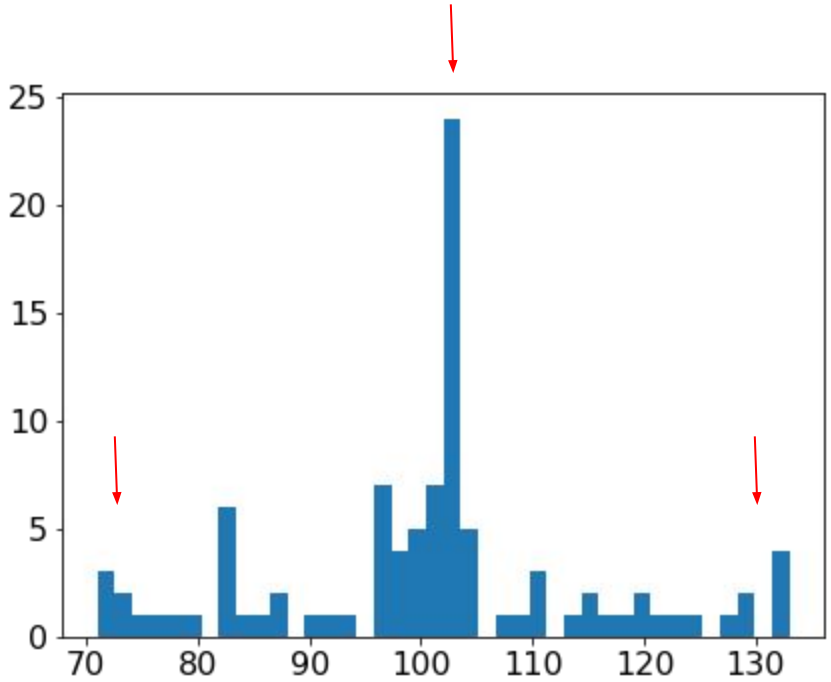




Flash CF>6.0

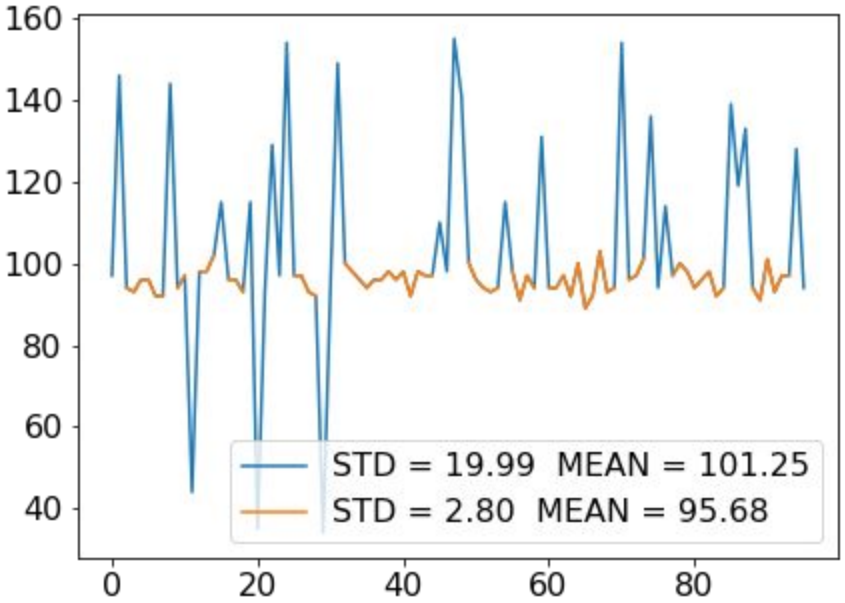
STD_{normal} / $STD_{clipped}$

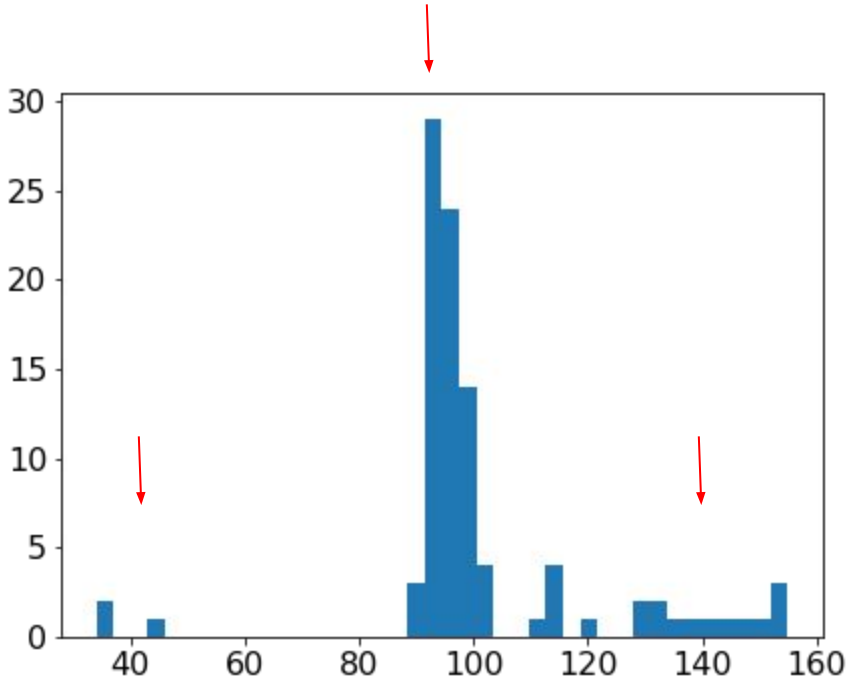




Flash CF>6.0

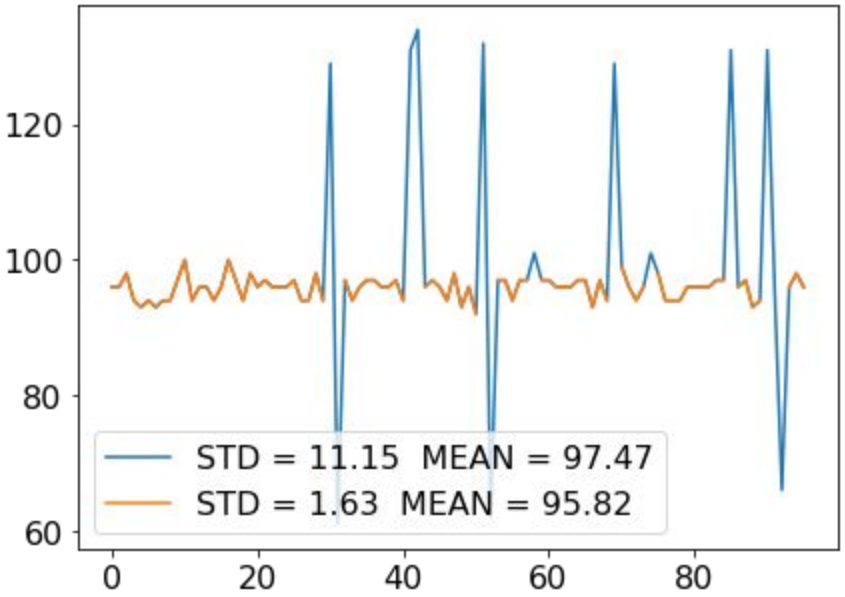
STD_{normal} / $STD_{clipped}$

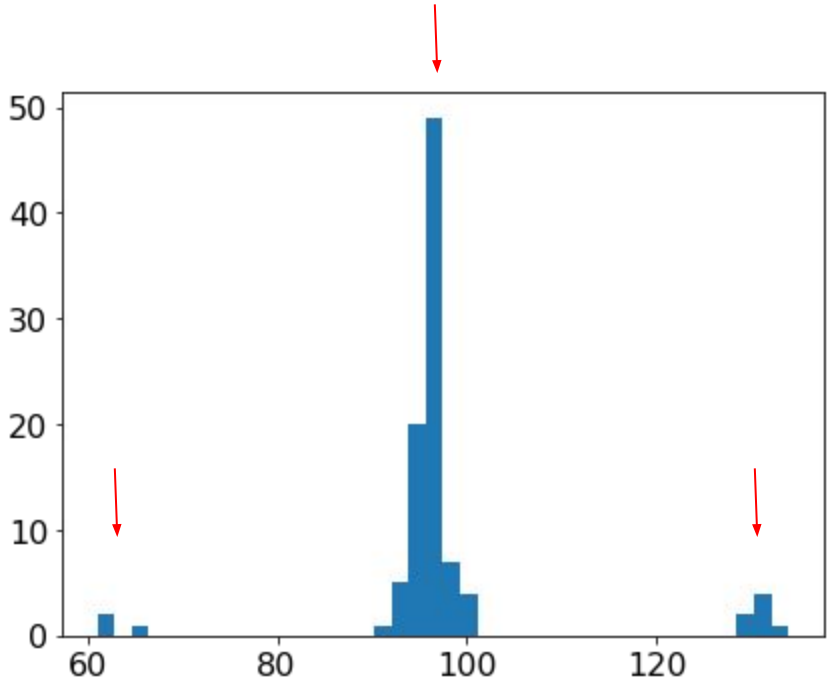




Flash CF>6.0

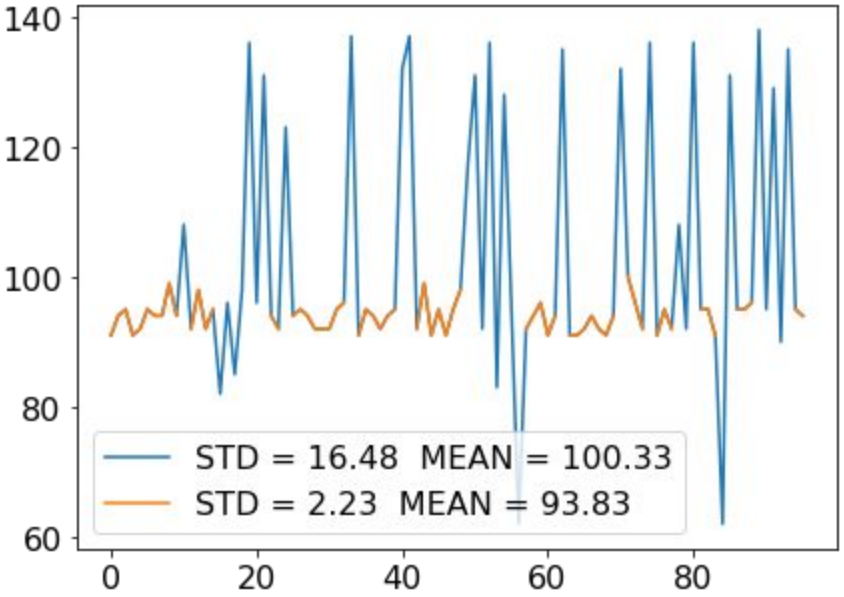
STD_{normal} / $STD_{clipped}$

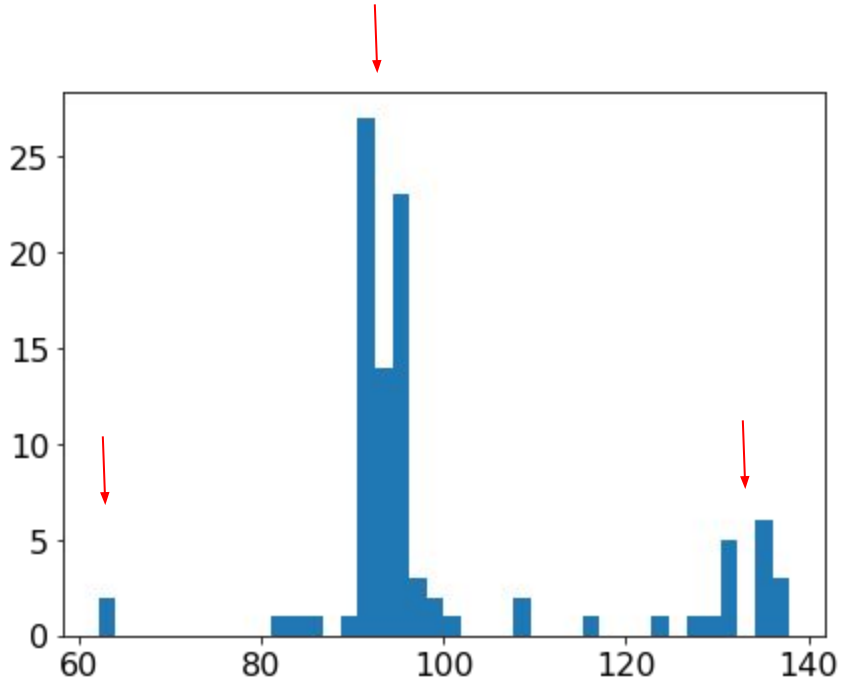




Flash CF>6.0

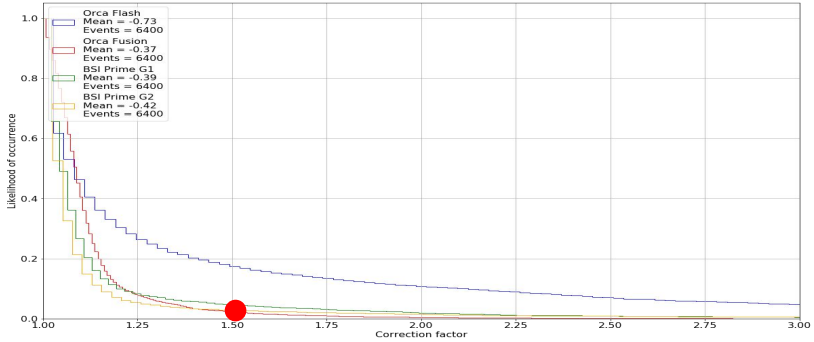
STD_{normal} / $STD_{clipped}$

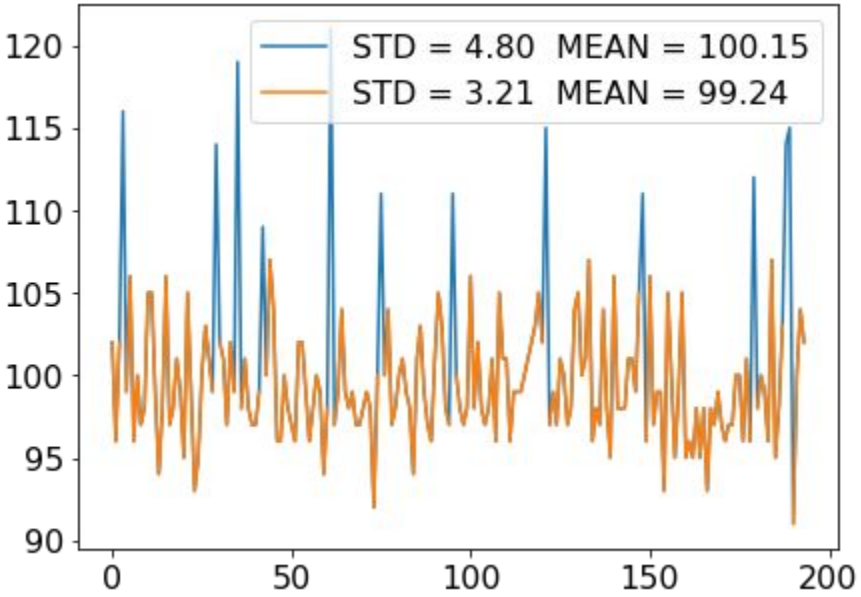


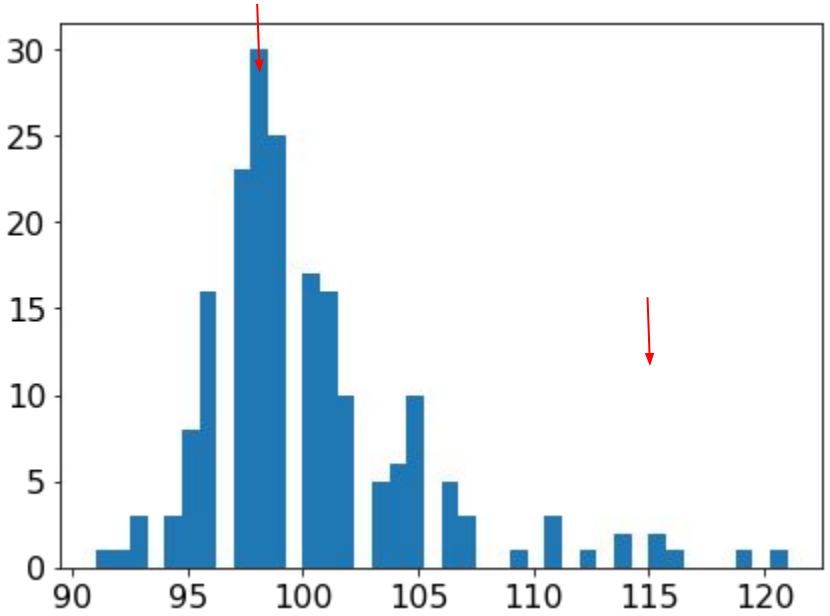


Fusion CF~1.5

STD_{normal} / $STD_{clipped}$

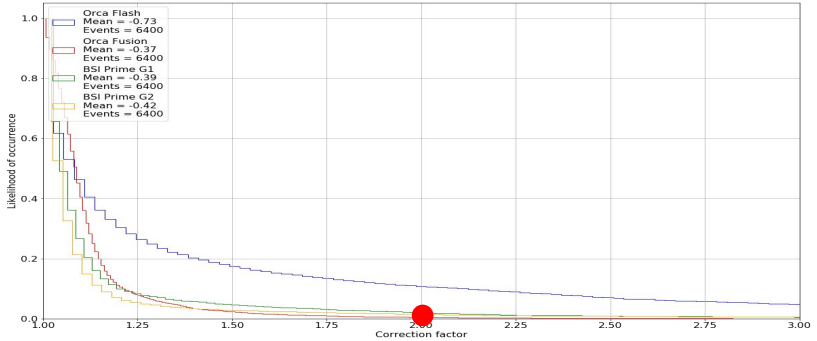


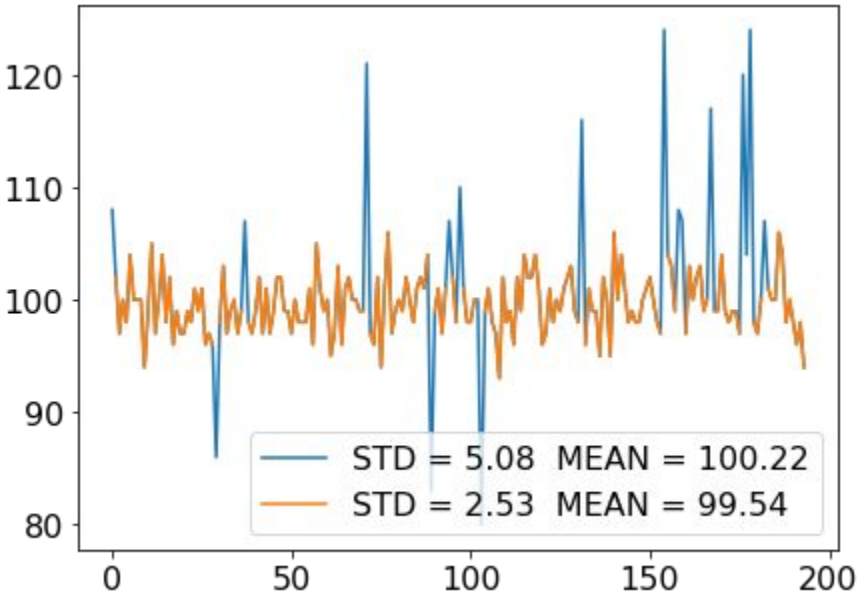


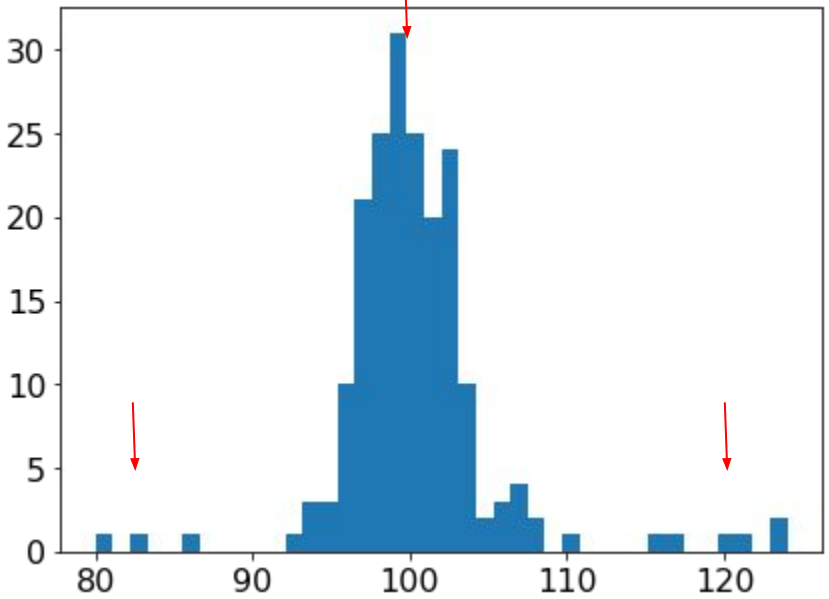


Fusion CF~2.0

STD_{normal} / $STD_{clipped}$

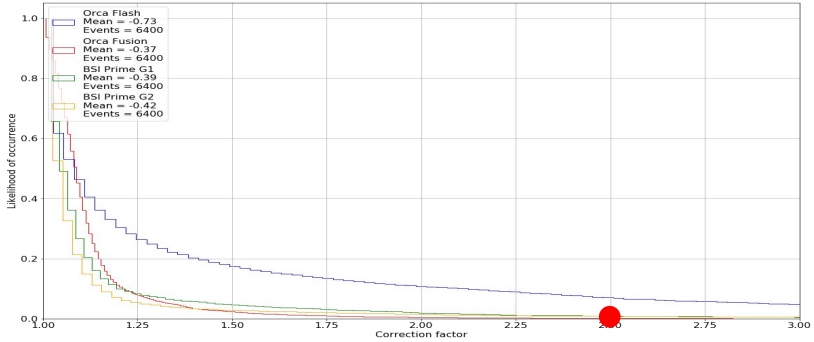


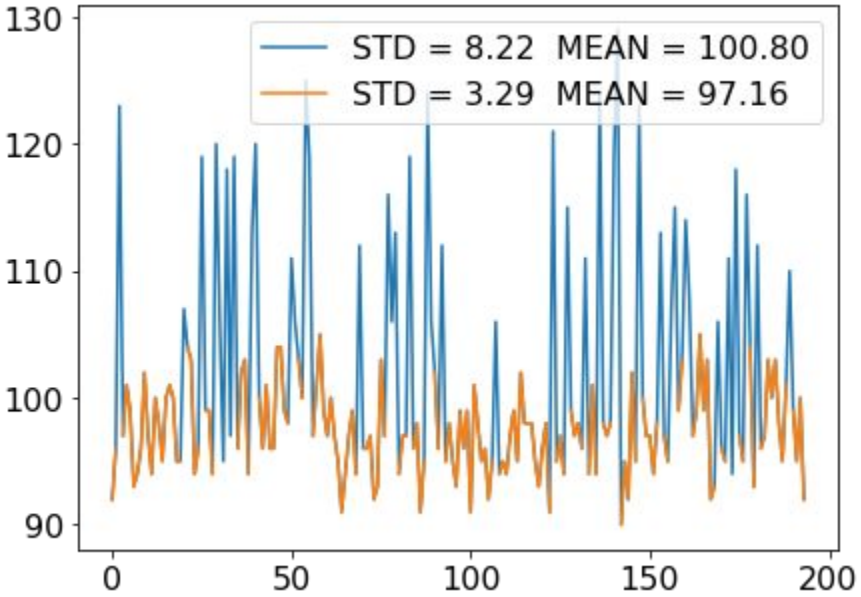


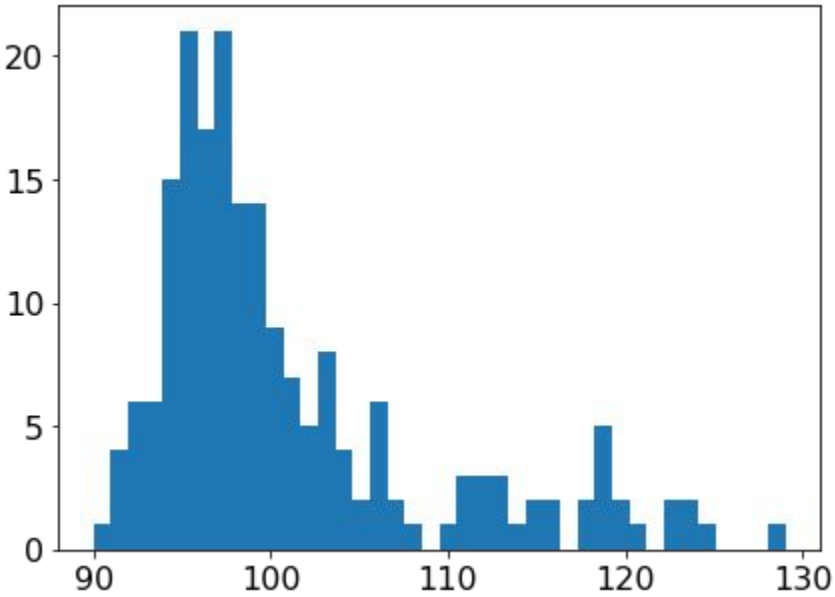


Fusion CF~2.5

STD_{normal} / $STD_{clipped}$

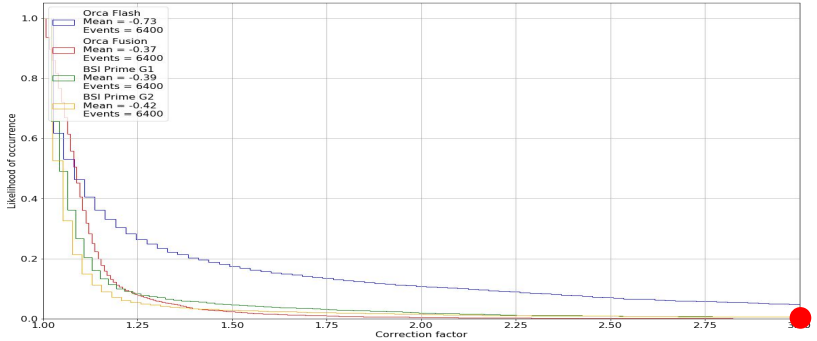


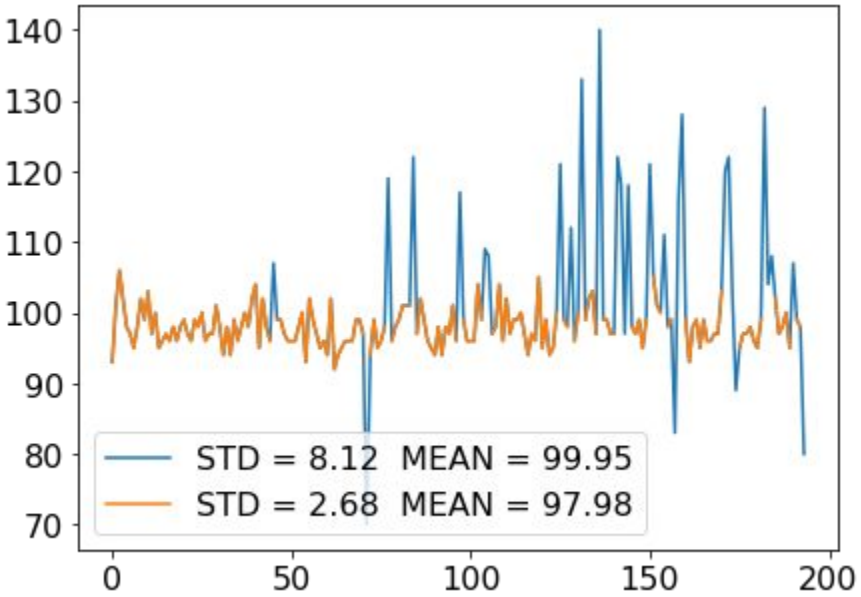


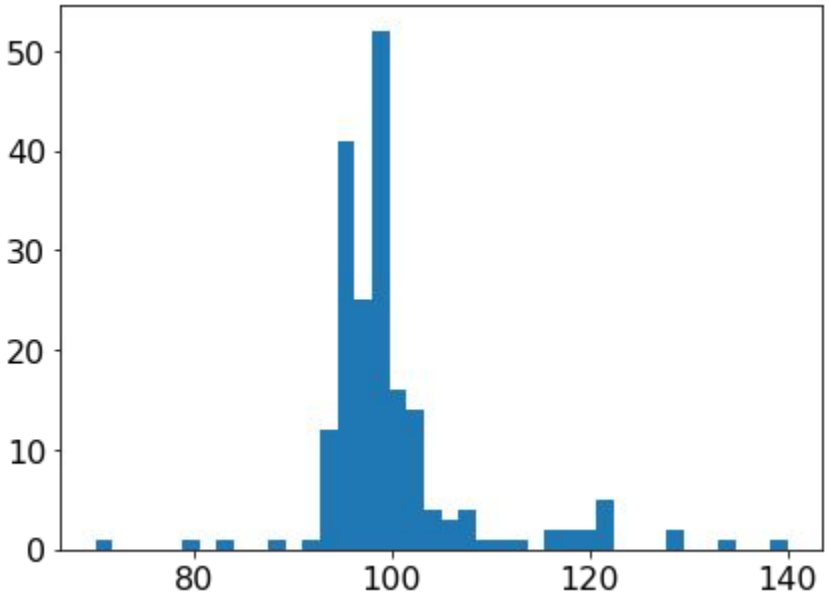


Fusion CF~3.0

STD_{normal} / $STD_{clipped}$



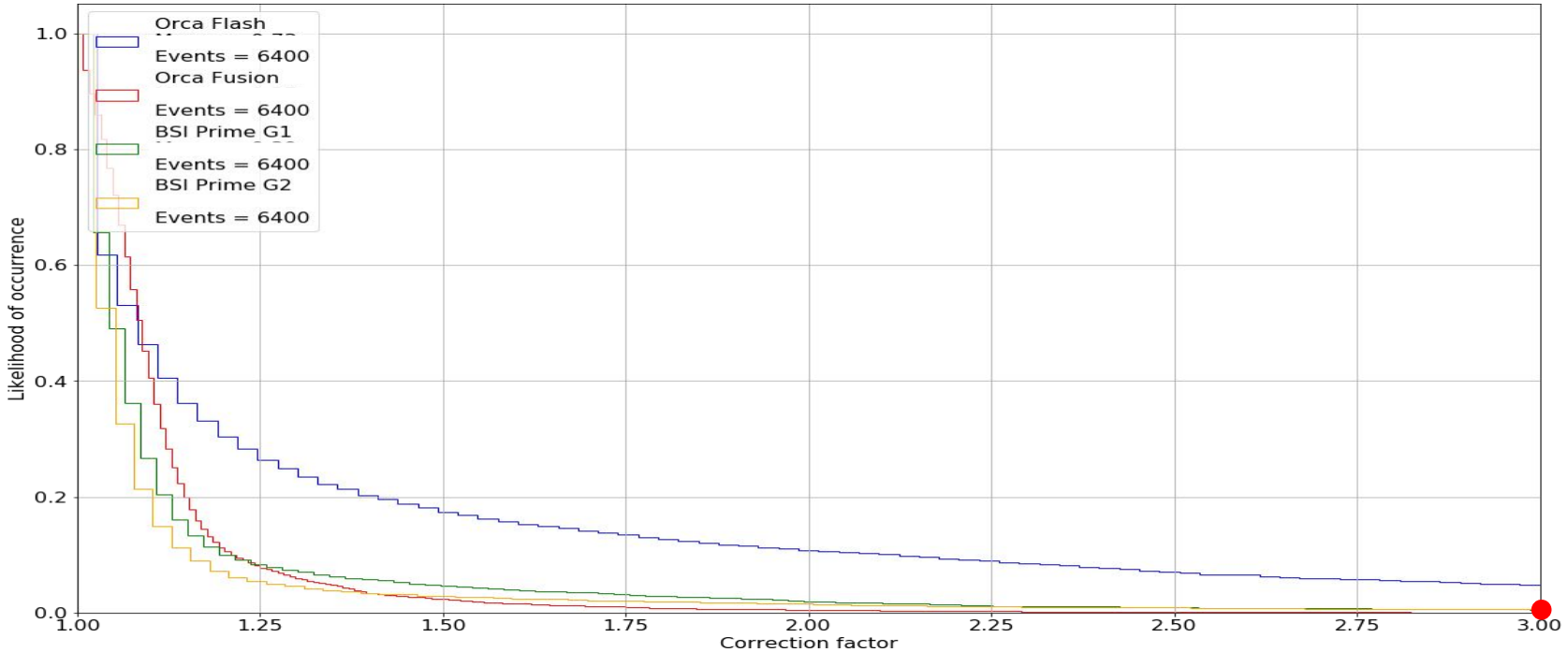




Fusion CF>6 NONE

STD_{normal} / $STD_{clipped}$

Only 2 cases in 6400 pixels with CF > 3 (0.03%)

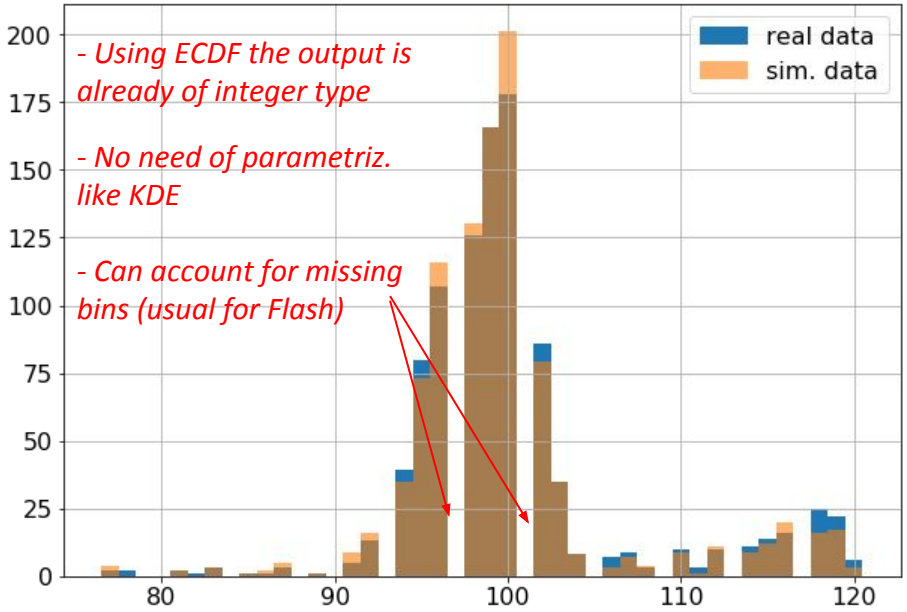


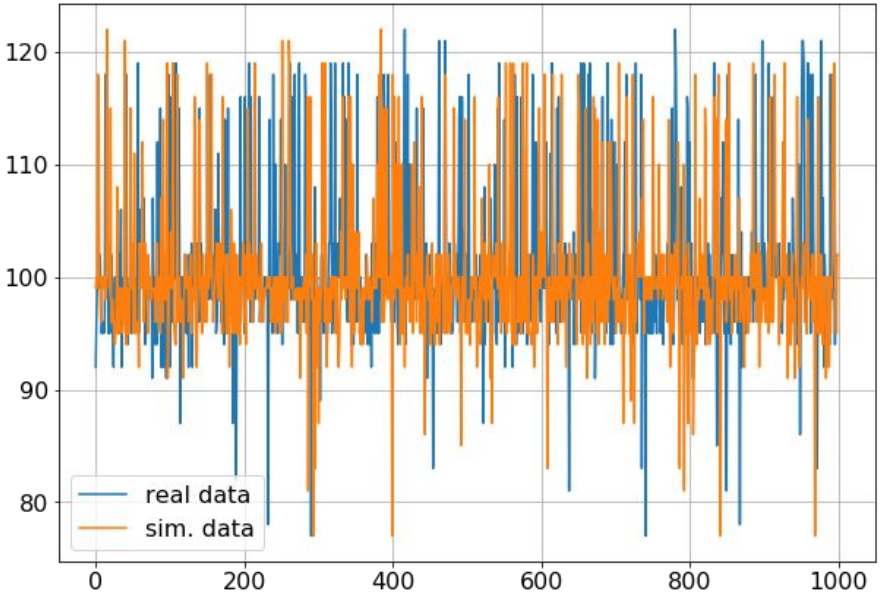
Back-up

Simulation using ECDF

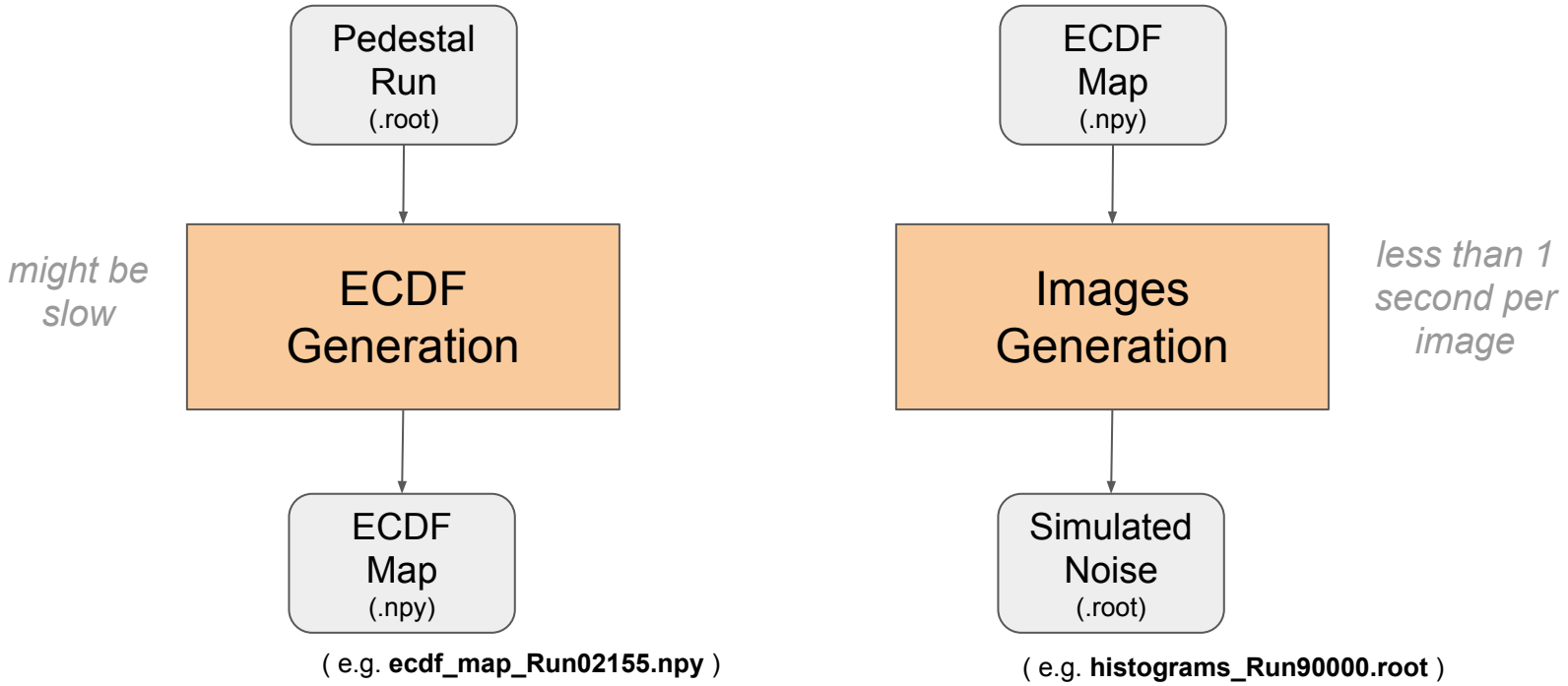
Simulation with ECDF (example)

Pixel (1,6) Flash sensor run 2054





Simulation with ECDF (block diagram)



Simulation with ECDF (functions details)

ECDF generation:

```
python3 NoiseSimCreateEcdf.py -n 100 -y 512 -r histograms_RunXXXXX.root
```

- *n* number of images to be taken into account to create the ECDF. If not defined, all run images will be used. The first five images are always skipped.
- *y* number of lines to be used in each chunk (in order to prevent out of memory however, the lower this number, the longer the processing time). This number must be an exact fraction of the number of rows of the sensor. If the code fails when trying to merge the chunk files because of memory error, use *-y -1* to run only the part of the code which merges the chunk files in disk.
- *r* is the .root filename to be used.

p.s. the output of this algorithm is a *.npy* file containing a ECDF for each pixel. Depending on the *n* and *y* values, this routine might take 90 minutes to run (tested on the cygno.cloud.infn computer for *n*=1000 and *y*=32). To make it faster *y* value must be high.

Images generation:

```
python3 NoiseSimCreateImgs.py -n 500 -r 90000 -f ecdf_map_RunXXXXX.npy
```

- *n* number of images to be generated.
- *r* output run number used in the name of the output file (e.g. histograms_Run90000.root).
- *f* is the .npy ECDF filename to be used.

p.s. the output of this algorithm is a *.root* file with the simulated images. It takes less than 1 second per image to run (tested on the cygno.cloud.infn computer producing 700 images in 500 seconds).